FEMC
Forest Ecosystem Monitoring Cooperative

Proceedings of the December 14, 2023 Forest Ecosystem Monitoring Cooperative Annual Conference:

Forests as Solutions to Climate Change, Biodiversity, and Well-being

Contents

Photos from Presentations clockwise from top left 1) Liz Thompson, 2) Anthony D'Amato, 3) Kyle Lima, 4) Andy Wood, 5) Bill Keeton

Forest Ecosystem Monitoring Cooperative

Providing the information needed to understand, manage, and protect the region's forested ecosystems in a changing global environment.

Established in 1990 and ratified in 1996 via a memorandum of understanding between the Vermont Agency of Natural Resources, the University of Vermont, and U.S. Department of Agriculture (USDA) Forest Service, the Forest Ecosystem Monitoring Cooperative (FEMC, formerly the Vermont Monitoring Cooperative) has been conducting and coordinating forest ecosystem monitoring efforts for thirty-three years.

Originally designed to better coordinate and conduct long-term natural resource monitoring and research within two intensive research sites in Vermont (Mount Mansfield State Forest, the Lye Brook Wilderness Area of the Green Mountain National Forest), FEMC efforts have since expanded to capture relevant forest ecosystem health work across the northeastern region with an expanding list of partners from Maine, Massachusetts, New Hampshire, New York, and beyond.

Today, the FEMC funding stems primarily from a partnership between the USDA Eastern Region State & Private Forestry as part of the Cooperative Lands Forest Health Management Program, the Vermont Department of Forests, Parks and Recreation, and the Rubenstein School of Environment and Natural Resources at the University of Vermont. Staff affiliated with the University of Vermont handle the majority of FEMC operations. While FEMC funding primarily supports ongoing monitoring, outreach and data management, contributions by the larger collaborative network are essential to the advancement of FEMC work. Cooperators participate on advisory committees, contribute to the data archive, and share knowledge across the region.

The current mission of the FEMC is to serve as a hub of forest ecosystem research and monitoring efforts across the region through improved understanding of long-term trends, annual conditions and interdisciplinary relationships of the physical, chemical and biological components of forested ecosystems. These proceedings highlight the breadth of activities undertaken by cooperative contributors and demonstrate the potential of large collaborative networks to coordinate and disseminate the information needed to understand, protect and manage the health of forested ecosystems within a changing global environment.

Online at https://www.uvm.edu/femc/

FEMC Steering Committee and State Coordinators – https://www.uvm.edu/femc/cooperative/committees

FEMC staff – https://www.uvm.edu/femc/about/staff

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Acknowledgments: The Forest Ecosystem Monitoring Cooperative would like to thank everyone who participated in the planning and production of this conference, from those who coordinated all the details behind the scenes, to our speakers and workshop participants who made the meeting such a success. This conference would not have been possible without the continued support from the Vermont Agency of Natural Resources, the U.S. Department of Agriculture, U.S. Forest Service Eastern Region State and Private Forestry, and the University of Vermont. We would especially like to thank Eli Ward, Alana Russell, Julianna White, Meg Fergusson, Jess Cancelliere, Logan Johnson, and Alison Adams for their work on the Annual Conference Planning Committee led by Elissa Schuett, as well as Heather Furman for her work in developing the plenary session and panel discussion; Dr. Alexandra (Ali) Kosiba, Dr. Michelle Kondo, and Tim Duclos for their work developing and participating in the panel discussion; and Dr. Allan Strong, Interim Dean of the Rubenstein School of Environment and Natural Resources for providing financial support to graduate students. We would also like to thank our invited speakers, working session organizers, and paper and poster presenters for their invaluable contributions. This work was produced in part through funding provided by the U.S.D.A. Forest Service Eastern Region State & Private Forestry.

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Introduction to the Proceedings

The Forest Ecosystem Monitoring Cooperative held its 33rd annual conference on December 14, 2023. The conference was held in-person at the Davis Center as well as online, making it the second year of offering the conference in a hybrid format. The conference theme was Forests as Solutions to Climate Change, Biodiversity, and Well-being. The conference provided a space to discuss trends in and methods to address a range of forest disturbances and disruptions. Practitioners and researchers discussed how the community of practice can promote the ability of forests to meet their potential as a key component of addressing many challenges for the thriving of socioecological systems.

The conference offered a plenary session and panel discussion; a summary of forest trends across the Northeast presented by Director Alison Adams; eight tracks for contributed talks including for the first time a track for NSRC-funded projects; four working group sessions; and a poster session. Justin Perry, the outgoing FEMC Steering Committee Chair, opened the conference with introductory remarks, followed by a brief presentation by FEMC Director Adams about the work FEMC has done this year, changes within the organization and its broader network, and what FEMC is looking forward to in the coming year. Alison introduced the plenary speaker, Heather Furman, who is the Director of the Appalachians Program at The Nature Conservancy. Heather shared reflections on the conference theme in the specific context of the Appalachian ecoregion, demonstrating with specific examples how forests are a critical component of addressing our climate and biodiversity crises while supporting human and more-than-human thriving. Heather followed her talk by moderating a panel discussion on the same topic with Dr. Alexandra (Ali) Kosiba (UVM Extension Assistant Professor of Forestry), Tim Duclos (Audubon Vermont Forest Program Senior Associate), and Dr. Michelle Kondo (US Forest Service Research Social Scientist).

More than 230 attendees registered for the conference, and approximately 30 attended virtually. The hybrid format provided maximum flexibility for attendees, allowing those located further afield to participate in the conference without the additional cost of travel, and also allowing those with health concerns or other considerations to attend. The virtual portion of the conference was offered via Teams, with a separate meeting link for each session. Attendees reported that this system was relatively easy to use and that the cameras and microphones provided a high-quality experience of the otherwise in-person event. Survey responses show strong support for continuing to offer a hybrid event in the future. Attendees indicated that they particularly appreciated the broad scope of the plenary talk, as it set the stage for the more in-depth explorations of specific topics covered in the contributed talks and working sessions throughout the day.

These proceedings include presentation summaries, abstracts, and outcomes compiled by FEMC staff as a resource for forest professionals from across the region. Additional materials, including presentation recordings, downloadable PowerPoint presentations are available at the conference webpage: [https://www.uvm.edu/femc/cooperative/conference/2023.](https://www.uvm.edu/femc/cooperative/conference/2023)

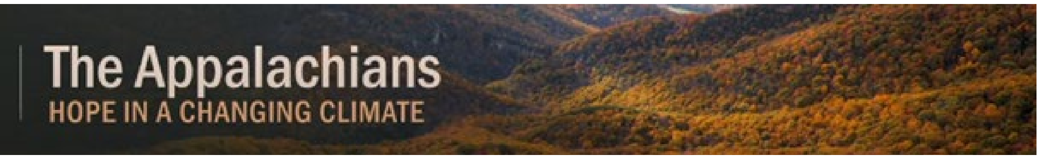
Forests as Solutions to Climate Change, Biodiversity, and Well-being

A conference planning committee was formed to define the conference theme and recommend plenary speakers to invite. The committee included Eli Ward (Connecticut Agricultural Experiment Station), Alana Russell (Rhode Island DEM), Julianna White (Northeastern States Research Cooperative), Meg Fergusson (University of Maine), Jess Cancelliere (New York State DEC), Logan Johnson (Maine TREE Foundation), Alison Adams (FEMC), and Elissa Schuett (FEMC).

Several sessions were held to discuss the conference theme, using guidance from the 2022 post-conference survey to identify the general theme of emerging technology as a topic. Members were interested in tying together the many roles of forests in addressing cross-cutting challenges in socio-ecological systems. The selected theme was “Forests as Solutions to Climate Change, Biodiversity, and Well-being.”

The plenary discussion was developed to set the stage for the day by situating forest stewardship, management, and conservation work within the context of the benefits of forests in the Appalachain eco-region. The planning committee identified Heather Furman, a long-time leader in forest conservation in the Northeast and recent appointee to Director of The Nature Conservancy's Appalachians Program. The panelists each brought a different perspective to the conference theme, from the role of forests in carbon storage and climate change mitigation (Dr. Kosiba), to the increasing attention to the ability of nature to improve human health (Dr. Kondo), to the critical role our forests play in maintaining biodiversity in the Northeast (Mr. Duclos). The plenary session and panel discussion provided a shared foundation on which the talks and sessions throughout the rest of the day built.

Plenary Presentation



Heather Furman, Appalachians Director for The Nature Conservancy kicked off our plenary to highlight the broader role that forests across our region play and our collective capacity to manage forests as solutions to the issues we currently face.

Many may not think of the forests in our backyard as globally important. But the vast landscape of biodiverse forests found across the region has been named as one of the four global priority regions by the Nature Conservancy based on its significant contribution to carbon sequestration, biodiversity, economic production and proximity to large populations. But its rank among the most important global ecosystems also stems from the threats it currently faces. Extreme climate events have impacted forested landscapes and human communities with increasing frequency and severity, with rural areas and marginalized communities among the most negatively impacted.

What do we as a conservation community need to do to address these challenges?

There are many ways that we can move forward and make the kind of progress we need to over the next decade. While work often occurs at local levels, every state has a critical role to play in maintaining forest connectivity, biodiversity and health so that forests can continue to sustain communities and serve as an insurance policy for the planet.

Ms. Furman emphasized that we will get more done by working smarter and working together. Because of the large proportion of forest land in private ownership this means we need to work directly with landowners to support families, communities and ecosystems. We need to be eager to work across state boundaries, organizational structures, decision making arenas and disciplinary silos. We need to be persistent and willing to use innovative approaches and tools to tackle this work across scales.

Heather Furman

Appalachians Director

The Nature Conservancy

"The forests right here across the northeast are among the most important places on the planet.....

This is why The Nature Conservancy has named the Appalacians as one of the four global priority regions.....

"I've never seen an opportunity for impact as exciting and critical as it is right now."

~ Heather Furman

We have a shared vision

- A connected and resilient network of lands and waters
- An intact forest that stores carbon and also provides a myriad of benefits for nature and people
- A personal connection to forested spaces

Opportunities for Impact

The Nature Conservancy has focused its efforts across three primary domains: Connectivity, Climate and Communities. Success in any of these domains requires our collective efforts across the region focus on tangible outcomes. Ms. Furman outlines specific management, planning and policy goals including:

Prioritize protecting strategic forested parcels to prioritize meaningful connectivity.

Improve forest health and productivity.

Make it economically viable for landowners to maintain forests as forests.

Ensure our energy and transportation infrastructure is complimentary to forest management goals.

Engage a diversity of stakeholders, empower local leaders and share resources.

We need to do this work within the context of deep community engagement, helping to build equitable approaches to achieving these goals while empowering local leadership. This is complicated by the need to work across organizations and scales, to take the long-view while also responding to urgent needs. Our success depends on our ability to navigate these challenges and work to leverage science, policy, funding, our values around equity and inclusion to ensure buy-in and commitment from a diverse group of stakeholders.

Dr. Ali Kosiba

Extension Assistant Professor of Forestry and Extension Forester

University of Vermont

Dr. Michelle Kondo

Research Social Scientist

USDA Forest Service Urban Forests, Human Health, and Environmental Quality Unit

Tim Duclos

Health Forest Program Senior Associate

Audubon Vermont

Panel Discussion

The Promise of Forests as Solutions

We were fortunate to bring three experts to the panel this year to provide their unique perspectives on the role of forests as solutions. This includes a focus on climate change impacts, forest carbon science and management (Ali Kosiba), biodiversity, stewardship and community engagement (Tim Duclos), public health and human well-being (Michelle Kondo).

Much of the discussion focused around **how to balance the sometimes competing objectives we have in managing forests so that we can focus more on the benefits discussed.** Panelists had several useful suggestions:

- Be careful of trying to prioritize any one goal or outcome. A focus on ecosystem forestry and silvicultural practices can help balance outcomes across multiple objectives.
- We need to approach forest management as a mosaic across the region. Our actions and objectives may differ across the landscape but should maximize what different forests are best suited to provide.
- Consider the issues of scale. How should our choices differ when we are working at different scales.

Panelists were also asked **what they believe are the most important skills or approaches we should be using to promote forests as solutions.** They agreed that there is no one tool or strategy we should be focused on, and that instead it is our diversity of approaches that will maximize our impact across the region. Thoughts included:

- Try different strategies and re-evaluate based on the outcomes. We need creativity and innovation moving forward.
- Build connections and partnerships with groups you wouldn't typically engage with. We need to branch out and extend our collaborative community. Focus on building relationships as solid forest management.
- The work that forest professionals do in the woods really does impact the broader socio- ecosystem. Let's make sure foresters are supported, resourced and empowered.

More Thoughts from the Panel

There is a level of evidence needed to justify investments in forests. the science is there, we need to emphasize and promote it to decision makers.

~Michelle Kondo

There is a lot of good work happening... We need to communicate this and tell our story better so that others are more willing to try new approaches.

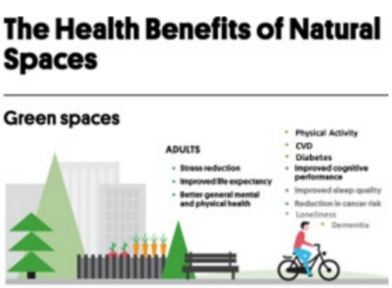
~Ali Kosiba

Birds are amazing indicators of forest health and an excellent "hook" to engage landowners. We need to remember to assess, monitor and manage forests considering metrics beyond the "trees."

~Tim Duclos

There is a growing body of research on the effects of living in and having greater access to green spaces. We need to consider and promote the value of forests as a public health amenity and something that we should be investing in.

~Michelle Kondo



How we do this work is as important as what we do. We are only going to be successful when the people who are being impacted have power and ownership over the decisions we make... we need to share power and resources ... and the benefits we gain from our efforts

~Heather Furman

Contributed Talks

Fire Adapted Forest Ecosystems

Creating a model for fire management monitoring in dry oak habitats

Ryan Rebozo[1], Jay Kelly[2], Jessica Ray[2]

[1]Vermont Center for Ecostudies, [2]Raritan Valley Community College

The use of prescribed fire as a management strategy for achieving ecological goals in oak forests has gained interest from land managers as they attempt to address a variety of objectives including attempting to imitate past disturbance regimes, address invasive species, and promote regeneration of target tree species. Addressing changes in tree composition as a result of mesophication is often cited as a focus of management efforts in these habitats, yet these processes and confounding effects of herbivory and plant competition are not always well understood at the local level. Prescribed burning has been hypothesized to benefit the regeneration of oaks by reducing competition, duff depth, or seed predation and increasing light and nutrient availability. However, the benefits of fire for oaks and other hardwoods are highly variable, with the outcomes depending upon initial site conditions, species, timing, size class structure, and other factors, and may also be detrimental or counterproductive to achieving these goals. This project represented an opportunistic study to develop baseline monitoring data for two dry oak habitats as well as compare post-fire forest response to adjacent and satellite control sites. The goal of this project was to develop a rigorous monitoring protocol using FIA phase 3 methodology, infrared deer density surveys and a focus on rare species response in order to help inform the future use of prescribed fire for ecological purposes in this uncommon natural community.

This monitoring effort identified a mixed response where the fire was effective at creating measurable changes in sapling mortality, and reducing leaf litter but unable to significantly consume the duff layer or stimulate the regeneration of oaks, both of which are stated goals for addressing mesophication. Local deer densities may already be impacting the regeneration of oaks beyond a lack of canopy gaps. Signs of spongy moth herbivory in the oak canopy and signs of beech bark and leaf disease throughout these forests suggest that much more light may be reaching the understory than densiometer-based measures of cover would suggest. The goal of stimulating oak regeneration through fire may be difficult to achieve in dry oak forests if deer herbivory and ambient deer densities are not taken into account and the resulting fire severity is unable to consume the existing duff layer.

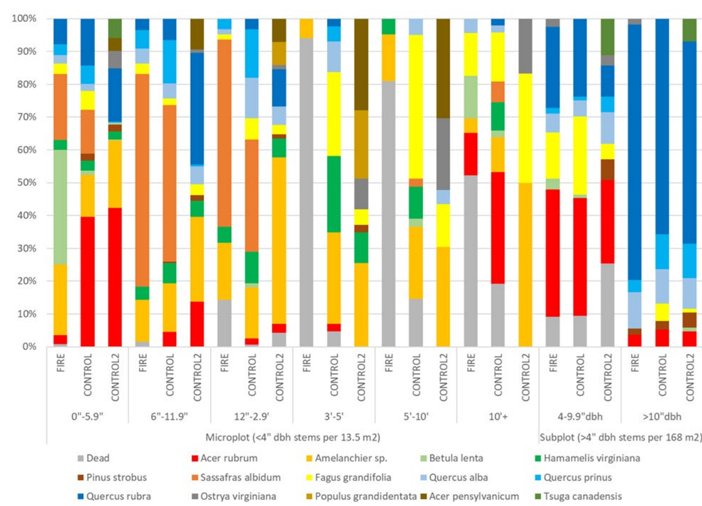


Figure 1 Percent composition of tree species by size class in fire treated and control plots.

Regeneration dynamics in northeastern pitch pine barrens under different restoration scenarios

Kathleen Stutzman[1], Anthony D'Amato[1], Kevin Dodds[2], Polly Weigand[3]

[1]University of Vermont, [2]U.S. Forest Service, [3]Central Pine Barrens Joint Planning & Policy Commission

Fire suppression and disconnection from historic fire regimes has had a distinct and significant impact on fire-adapted natural communities, changing community structure, composition, and diversity, as well as fuel availability. The mesophication and densification associated with fire suppression in Eastern US forests has favored shade-tolerant and fire-sensitive species, creating new stable closed forest states, which will not easily revert to pre-suppression fire-adapted communities. Novel stressors facilitated by climate change have the potential to further degrade fire-adapted communities.

For northeastern pitch pine barrens, fire suppression and the range expansion of Southern Pine Beetle (Dendroctonus frontalis) present substantial and imminent challenges to the restoration and maintenance of these rare, endemic communities. This study examines and evaluates the response of tree regeneration to a range of different restoration scenarios in pitch pine barrens across Maine, New Hampshire, Massachusetts, and New York. Restoration scenarios examined included thinning, spring prescribed fire, fall prescribed fire, and mowing followed by prescribed fire with monitoring also occurring in untreated areas. The overall goal of this work is to formulate region-wide best management practices to restore and maintain pitch pine barrens and to inform cultural and ecological objectives. For this talk, preliminary findings on the relationship between restoration scenarios and tree regeneration response will be discussed (Figure 2).

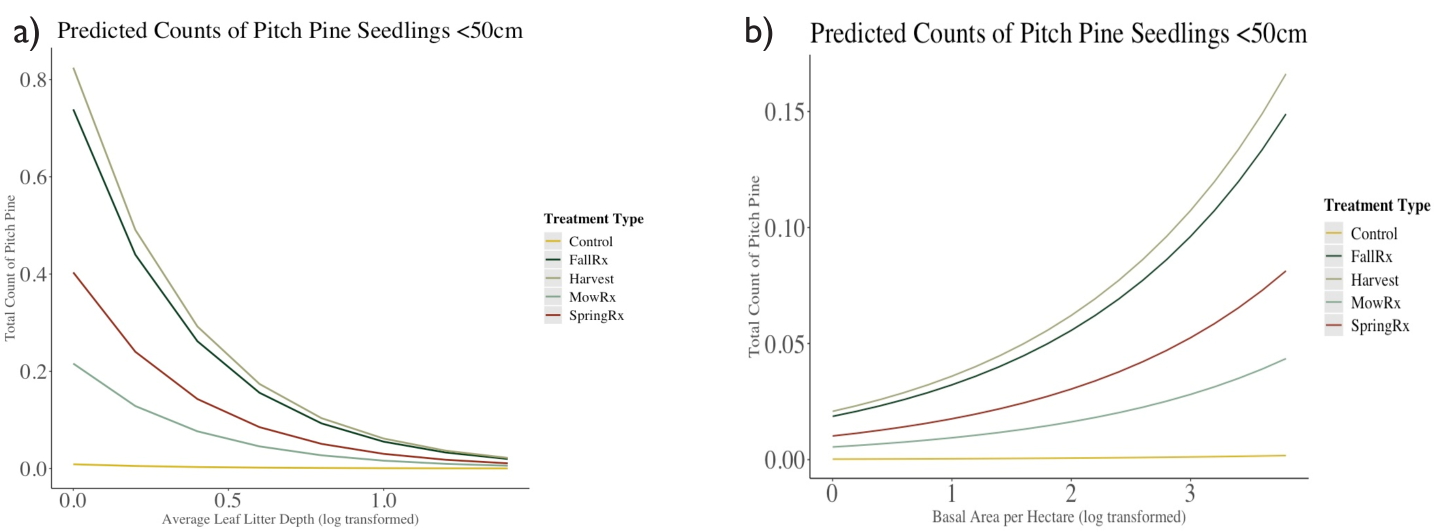


Figure 2 a) Pitch pine seedling counts decrease as leaf litter depth increases. b) Pitch pine seedling counts increase with basal area.

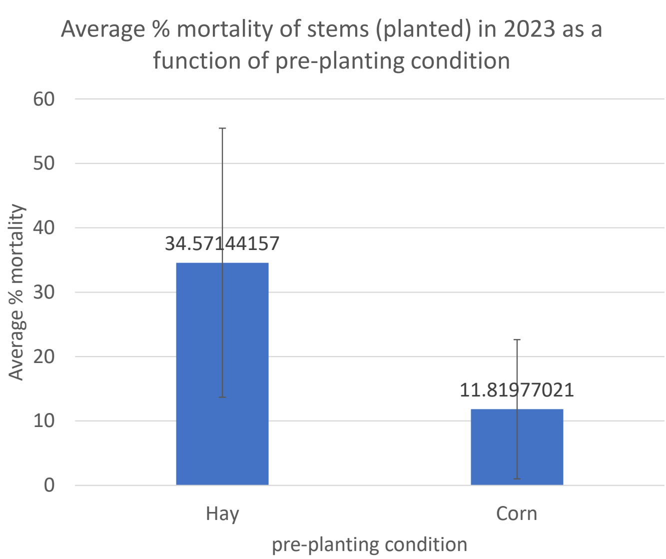
Riparian Forest Management

3 years of monitoring 15 riparian tree plantings on ANR land

Sam Puddincombe[1], Will Eldridge[1]

[1] Vermont Fish and Wildlife Department

Riparian restoration is as much an art as a science. To better inform the practice in Vermont, VFWD has spent the last three summers monitoring 81 plots in riparian tree plantings on 15 ANR owned parcels. Most plantings were not set up as experiments and sites varied in age of planting during the first year of monitoring (0-3 years post-planting), pre-planting conditions (retired ag, former athletic field, former berm, restored wetland, construction staging area), planting strategy (bareroot vs. live stakes, evenly spaced vs. clustered, professional vs. volunteer, planting density), and post-planting maintenance (competitor suppression, exclusion fencing). Natural tree regeneration was also monitored along with ground cover and species of and distance to potential source trees to evaluate passive restoration. Growth, survival, density and natural regeneration varied among sites and treatments, but many variables were confounded preventing robust analyses. Preliminary qualitative analyses lead us to believe pre-planting conditions had the biggest effect on survival and natural regeneration. Specifically, survival and natural regeneration were lowest in retired hay fields (Figure 3). Post-planting maintenance also affected survival of planted stems (sometimes negatively due to herbicide drift) but there was no clear effect on natural regeneration. Planting strategy seemed to have the least effect on survival and natural regeneration, and as a result the final stem density was correlated with the initial planting density. The results suggest altering pre-planting conditions of hay fields through site-preparation may be warranted. Passive restoration through natural tree regeneration may be possible at most types of sites other than hay fields, but natural regeneration is usually patchy and may not be apparent for 3 or more years of restoration. When the goal is to establish vegetated cover quickly, for example to curb infestation of exotic invasive plants, the liberal use of live stakes can be an economical alternative.



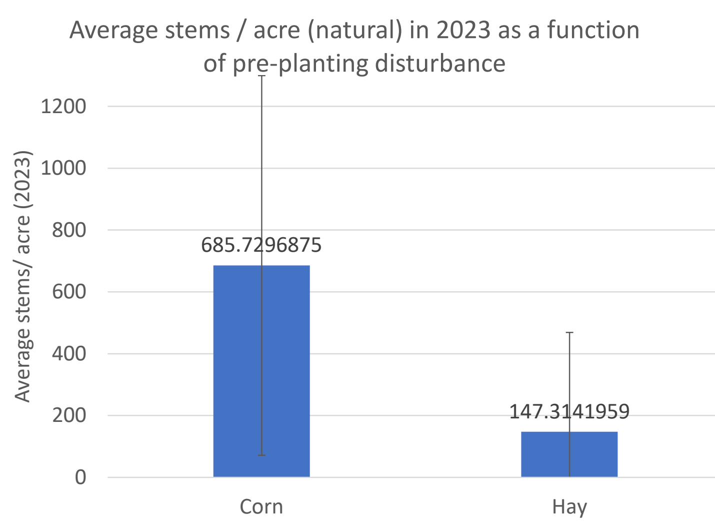


Figure 3 High disturbance conditions (corn) had higher success than low disturbance conditions (hay) in both planting and natural regeneration sites.

Remnant old trees enhance large woody debris loading in low-order streams at the Hubbard Brook Experimental Forest

William Keeton[1], **Stephen Peters-Collaer**[1]

[1]University of Vermont

Secondary forests in New England are recovering from 19th century land-use along multiple pathways of development. Yet, it remains poorly understood how highly dynamic interactions between forests and streams will shift as stands develop late-successional/old-growth characteristics. Previous research has suggested that structural development in riparian forests will enhance important functions, including carbon storage and flood resilience, but sources of variation in riparian functionality remain poorly explored. This study investigated the effects of riparian forest structure, including indicators of late-successional development, on wood loading in low-order, headwater streams draining mature northern hardwood forests at the Hubbard Brook Experimental Forest (HBEF) in New Hampshire. We assessed in-stream large woody debris (LWD) along 300m longitudinal transects within 13 stream reaches using the line-intercept method (LIM) and a total wood census (TWC). We sampled in-stream habitat features, such as pools and debris dams, and measured attributes of riparian forest structure. We applied multi-hierarchical Bayesian models to investigate the effects of forest structure on LWD loading and the effects of LWD loading on pool- and debris dam frequency. Forest structure affected LWD loading, indicating strong effects of big tree density and dead tree density among other structural attributes. Debris dam frequency strongly depended on LWD frequency, while pool frequency depended more strongly on stream geomorphology. The LIM and the TWC sampling methods delivered significantly different results when comparing 50 m stream sections. Our findings highlight the importance of evaluation of adequate transect lengths for further applications of the LIM (Figure 4). We conclude that biological legacies like remnant old-growth trees, large secondary trees, and standing dead trees are important structural attributes promoting LWD in low-order streams. These effects translate into both enhanced in-stream carbon storage (the subject on on-going research) and greater aquatic habitat complexity. Practices that retain or restore large trees within riparian corridors are likely to yield similar benefits.

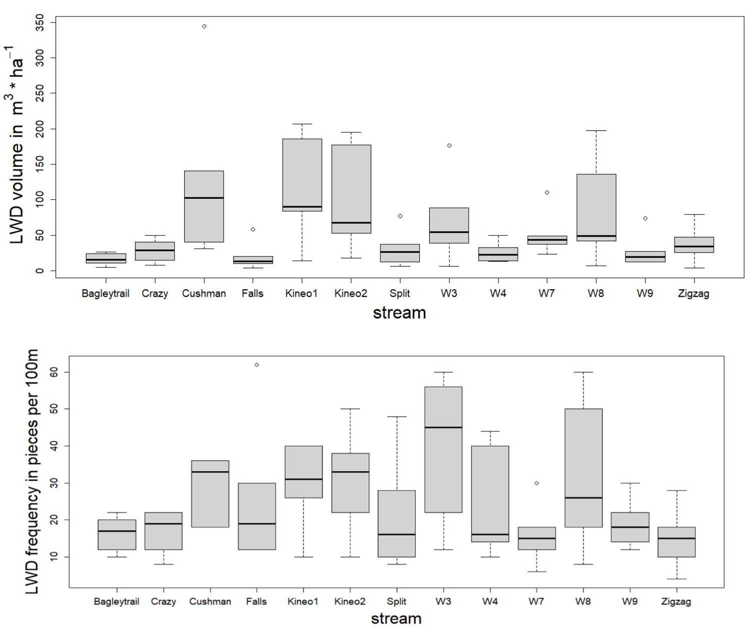


Figure 4 Large Woody Debris (LWD) loading is highly variable both within (50 m long subsections) and among stream reaches (300 m length)

Winter Monitoring and Management

New Hampshire mountain snow monitoring

Georgia Murray[1], Maya Shyevitch[1], Jordon Tourville[1], Sarah Nelson[1], Miriam Ritchie[1]

[1]Appalachian Mountain Club

There is clear evidence that the Northeastern U.S. snow season is shrinking, yet snow distribution in montane environments is complex with some areas able to retain snow longer. Therefore, the need for more distributed snow measurements is vital to understanding the ecological and economic impacts of changing winters. The Appalachian Mountain Club (AMC) operates the Pinkham Notch, New Hampshire National Weather Service COOP station with a 90+ year record of snowfall and snow depth. More recently, AMC began tracking daily snow depth at 4 backcountry huts and have estimated snow melt timing from a network of HOBO temperature loggers across the White Mountains, N.H. Expansion of a citizen-science effort called Community Snow Observations, where recreationists make snow depth measurements, is also filling in gaps across montane landscapes. Our study will combine AMC's data with other snow monitoring initiatives in the region to develop snow distribution and melt timing models, refining estimates as our spatial resolution improves. Results to date show Pinkham Notch, NH, at just over 600 meters elevation, has seen snowmelt occur 15 days earlier over a 92 year period. We compared snowmelt timing at forested plots, estimated by HOBO measurements of air temperatures, to daily human-observed snow stake measurements nearby, and found that the HOBO stations recorded earlier snowmelt than snow stakes. We attributed the difference to the height of the HOBO logger and premature melt from the HOBO radiation shield. High spatial variation in mountain environments and differences among methodologies point to a need for enhanced and harmonized snow data in Northeast montane areas. We will present on our continued evaluation using HOBO estimates and comparisons across our snow stake plots, as well as our roadmap for future snow analysis. We aim to develop snow distribution and snowmelt timing models to enable AMC's and partners' broader mountain monitoring efforts.

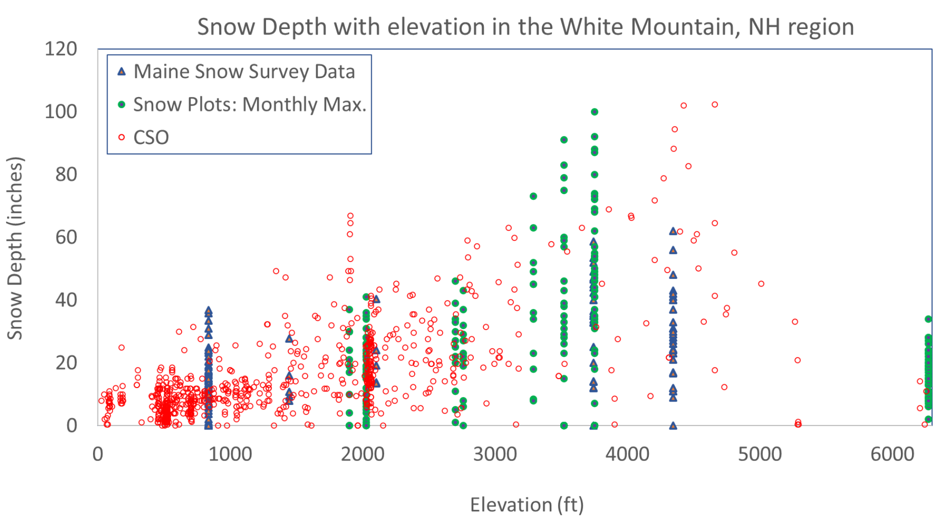


Figure 5 Community snow observations contributes to snow depth data in the White Mountains.

Creating a common language for BC ski zone management

Kathryn Wrigley[1], Luke O'Brien[1]

[1]VT Department of Forests, Parks and Recreation

The Vermont Backcountry Ski Handbook was developed with input from the Vermont Department of Forests, Parks & Recreation, the Vermont Department of Fish & Wildlife, the US Forest Service, and the Catamount Trail Association. It covers natural resource and social considerations, building partnerships with public and private land managers, delineating backcountry ski zones, and outlines the process for implementation, construction, and maintenance of ski zones. It's a complete how-to guide for creating high quality, sustainable backcountry ski terrain in a cooperative fashion with forest land managers.

By emphasizing a common language around ski zones, The Vermont Backcountry Ski Handbook will not only help land managers better administer their land for backcountry users, it will also help skiers and riders better understand and appreciate the concerns of land managers. This greater understanding between stakeholders should lead to stronger, more cooperative relationships. Come learn about this tool and the best management practices for backcountry ski zone implementation and management (Figure 6.

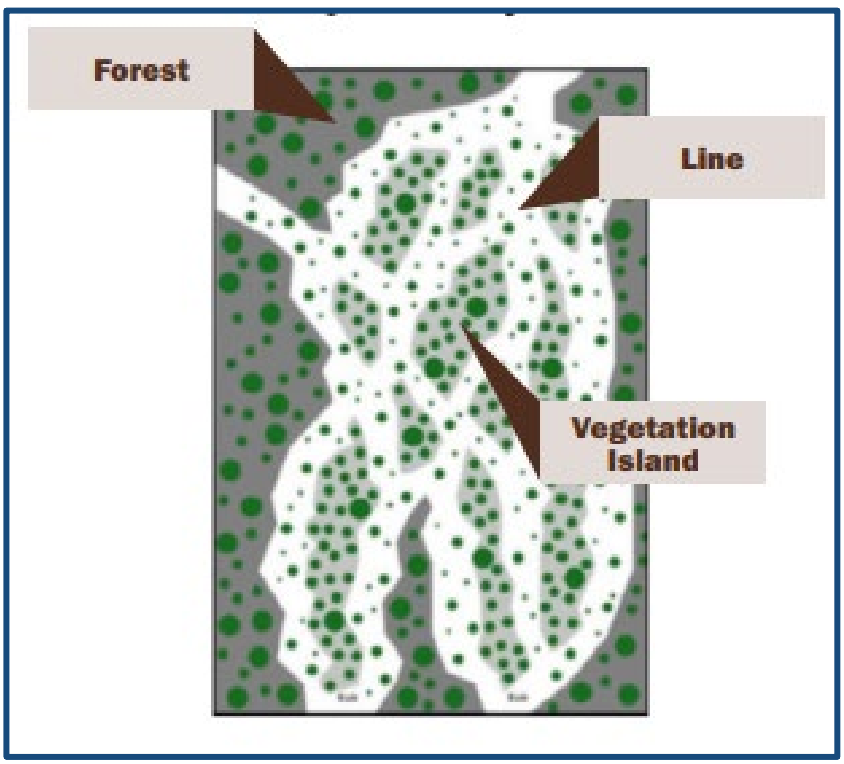


Figure 6 Use of vegetation islands is one recommendation included in the Vermont Backcountry Ski Handbook. These features provide challenge and diversity to the ski terrain while protecting forest diversity and ecosystem functions.

Community and Citizen Science

Community science as a tool for understanding mercury contamination at local and national scales

Celia Chen[1], Sarah Nelson[2], Christine Gardiner[1], Vivien Taylor[1]

[1]Dartmouth College, [2]Appalachian Mountain Club

Mercury (Hg) pollution is a persistent and prevalent threat to environmental health across the globe. In aquatic systems, inputs of inorganic Hg can transform into the more toxic and bioavailable organic form, methylmercury (MeHg). MeHg biomagnifies in aquatic food webs and can be transferred to terrestrial food webs. Mercury is of concern in northern New England due to relatively enhanced atmospheric inputs from long-range transport and legacy point-source pollution. The Dragonfly Mercury Project (DMP) is a nationwide study led by the National Park Service (NPS) and U.S. Geological Survey (USGS), in collaboration with Dartmouth College and the Appalachian Mountain Club (AMC). It has established a surveillance network for Hg in protected lands across the US by engaging community volunteers in the collection of dragonfly larvae as Hg biosentinels (Figure 7). The data generated through the DMP allowed for the creation of an integrated impairment index that informs wildlife and human health Hg risk based on dragonfly larvae Hg concentrations. In collaboration with the AMC, the Dartmouth DMP has been run for 13 years with schools in Vermont and New Hampshire and was expanded to include sites in White and Green Mountain National Forests and communities in Lawrence and Lowell Massachusetts. This talk will describe past and ongoing DMP programs run in collaboration with the Appalachian Mountain Club. These efforts provide spatial mercury data for New England states that are susceptible to hotspots of mercury bioaccumulation but lack consistent long-term monitoring. The utilization of community science efforts provides benefits of increased investment in and knowledge of local ecosystems as well as larger spatial and temporal patterns of Hg risk.

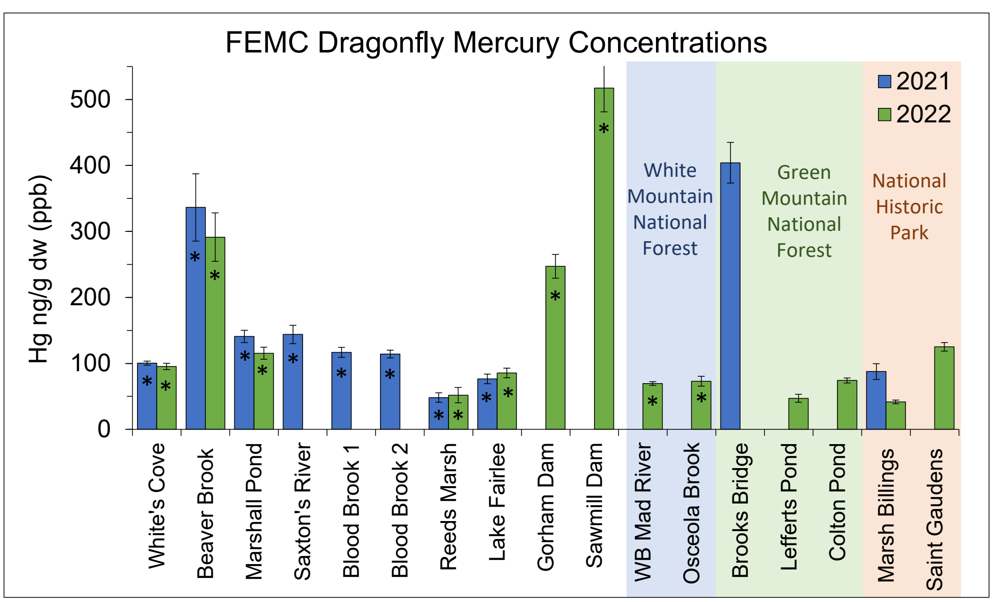


Figure 7 Mercury concentration in dragonflies were measured in 2020 and 2021 at 17 sites in Massachusetts, New Hampshire, and Vermont, engaging 300 people in citizen science.

A real-time detection and monitoring system based on citizen science observations

Kyle Lima[1], Abraham Miller-Rushing[2], Nicholas Nicholas[1]

[1]Schoodic institute at Acadia National Park, [2]US National Park Service

Climate change, invasive plants, and forest pests are rapidly changing forests in the northeastern United States. Detecting these changes early is critical to implementing cost-effective management and limiting the impact of disturbances. However, many forest disturbances likely go undetected until it is too late for cost-effective management because current monitoring protocols are labor intensive, focus on small monitoring plots, and require specialized skills. An early detection system that can be applied over large spatial scales is needed to help improve management. Schoodic Institute and Acadia National Park have attempted to fill this critical monitoring gap by developing an early warning system using tools in R that builds upon the large, and growing, number of citizen scientists already interacting with and visiting protected areas. We will present on the project that was built for Acadia National Park that consists of an auto-updating interface that summarizes reports of species park managers have identified as a monitoring priority (i.e., forest pests, invasive species, new species to the park, and threatened and endangered species). By working with citizen scientists in this capacity, we are able to keep monitoring costs low, engage the community in critical science, and detect species at a scale and rate likely not feasible otherwise. This project was built with customizability as a priority, and therefore the citizen science analysis workflow and interface are easily transferable to any protected area and the list of species can be specific to any manager's needs.

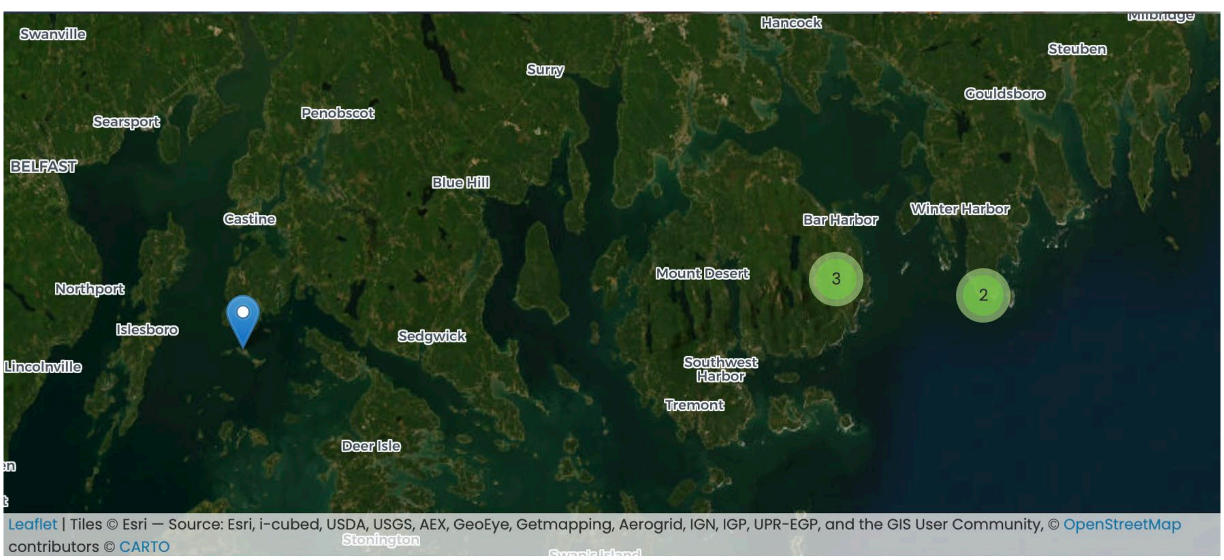


Figure 8 An example map of observations submitted by citizen scientists into iNaturalist and eBird in Acadia National Park. The map is interactive and is auto-updated.

Old Forests, Land Use, & Planning

Wildlands in New England: Past, present, and future - new data and a call to action

Elizabeth Thompson[1]

[1]Wildlands, Woodlands, Farmlands, and Communities

Wildlands In New England was published earlier this year by the Wildlands, Woodlands, Farmlands, and Communities (WWF&C) collaborative. The 112-page report offers a definition of WIldlands, a list of the values of WIldlands, abundant background on Wildlands concepts, and a report on the findings of the multi-year study that analyzed in detail over 400 potential Wildland properties throughout the region. The key finding is that the region is 80% forested but only 3.3% of the total land area is considered Wildland. To meet the goals of Vermont Conservation Design, the WWF&C vision, Vermont's new Biodiversity Bill, and the national and global 30x30 goals, much more needs to be done.

Many partners provided access to legal documents, management plans, and other agreements, formal and informal, to allow us to calculate the amount of wildland in the region. Each property submitted was scrutinized to determine if it met the criteria laid out. The data are assembled in an online database which is updated regularly based on submissions from partners.

I will describe the report and its findings, will demonstrate the online portal, and will describe the process and criteria for submission of new data. Finally, I will offer some illustrated examples of recently protected Wildlands.

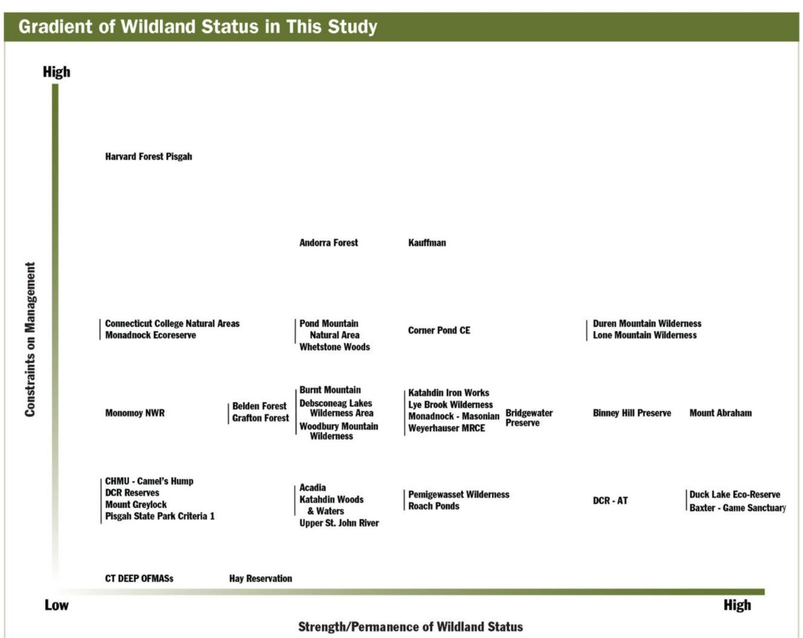


Figure 9 Wildlands in the region have varying levels of strength of management and permanency.

The status of current and future old forests in Vermont

Robert Zaino[1]

[1]Vermont Fish and Wildlife Department

The conservation and restoration of old forests are important parts of many large-scale conservation plans, including Vermont Conservation Design, and the Wildlands, Woodlands, Farmlands & Communities initiative. While old forests have been often studied in Vermont, there is still a lack of comprehensive data on the extent and condition of existing old forests, so the Vermont Fish and Wildlife Department's Natural Heritage Inventory has begun to map and track old forest natural communities. I'll summarize the data we've collected so far, and our inventory efforts to identify previously unknown old forest examples. I'll also present results of an analysis of expected future old forests (forests of any age now that are likely to develop into old forests under natural processes), and how their spatial distribution and natural community types contribute to meeting the old forest targets in Vermont Conservation Design (Figure 10).

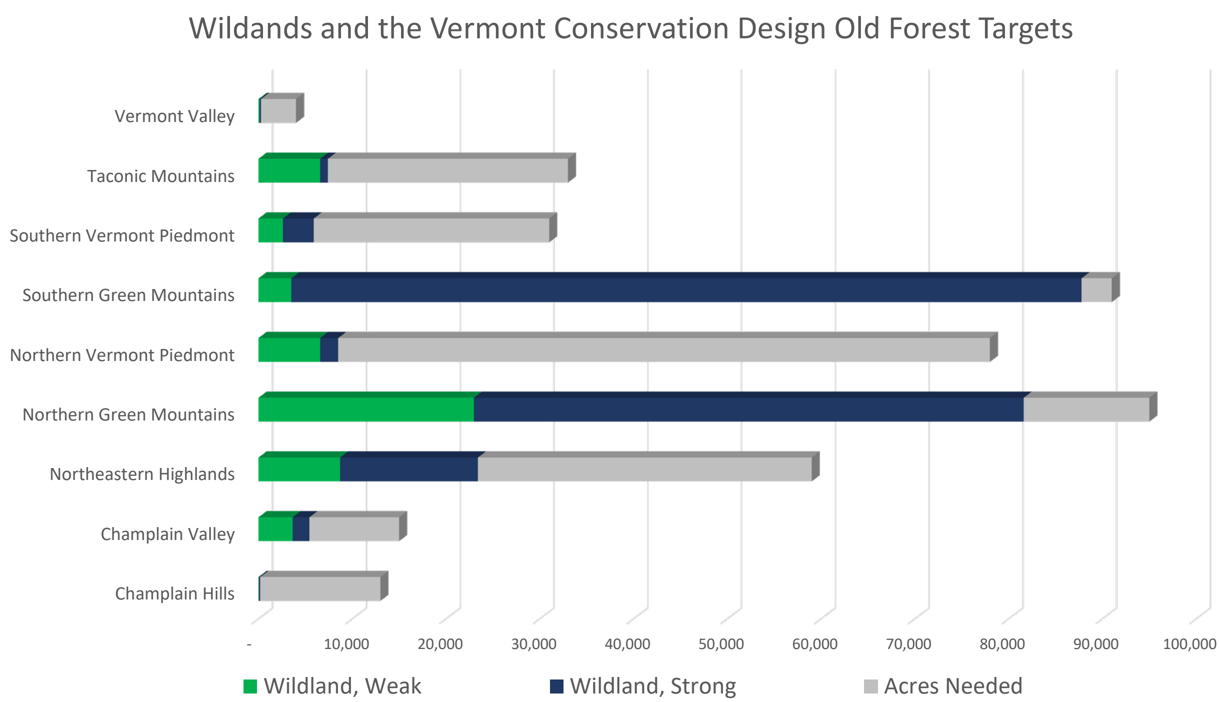


Figure 10 Wildlands in Vermont are an opportunity for future old forests, which are well-represented in the Green Mountains, but poorly represented elsewhere in the state.

Tracking parcelization and land use change in forests to inform policy and planning

Jamey Fidel[1], Deb Brighton[2], Kayla Patel[1], Brian Voigt[3]

[1]Vermont Natural Resources Council, [2]Consultant, [3]Consultant

Forests play a critical role in maintaining biodiversity, ecosystem integrity, and serving as a natural solution to climate change, but land use trends demonstrate we are fragmenting and converting forests due to development and land use change. In order to maintain the resiliency and integrity of forests, it is necessary to understand where parcelization and land is subdivision is occurring, and the rate at which it is occurring. This FEMC funded project responded to this need by building a database to examine trends on private land in Vermont by using Grand List (property tax) land classification and Use Value Appraisal Program data from 2005 to 2020 (Figure 11). In addition, this project created a Parcelization Website to examine trends at the town, county, regional planning commission, and state level to inform housing, conservation, land use policy. The presentation will provide an overview of land use and parcelization trends in the state, with particular attention to trends demonstrating the increasing loss of large, undeveloped woodland parcels. In addition, the presentation will share the results of a case study utilizing Property Transfer Tax Return data to perform GIS spatial analysis of subdivisions in forests. Recommendations for maintaining the integrity forests through land use and state policy will be provided.

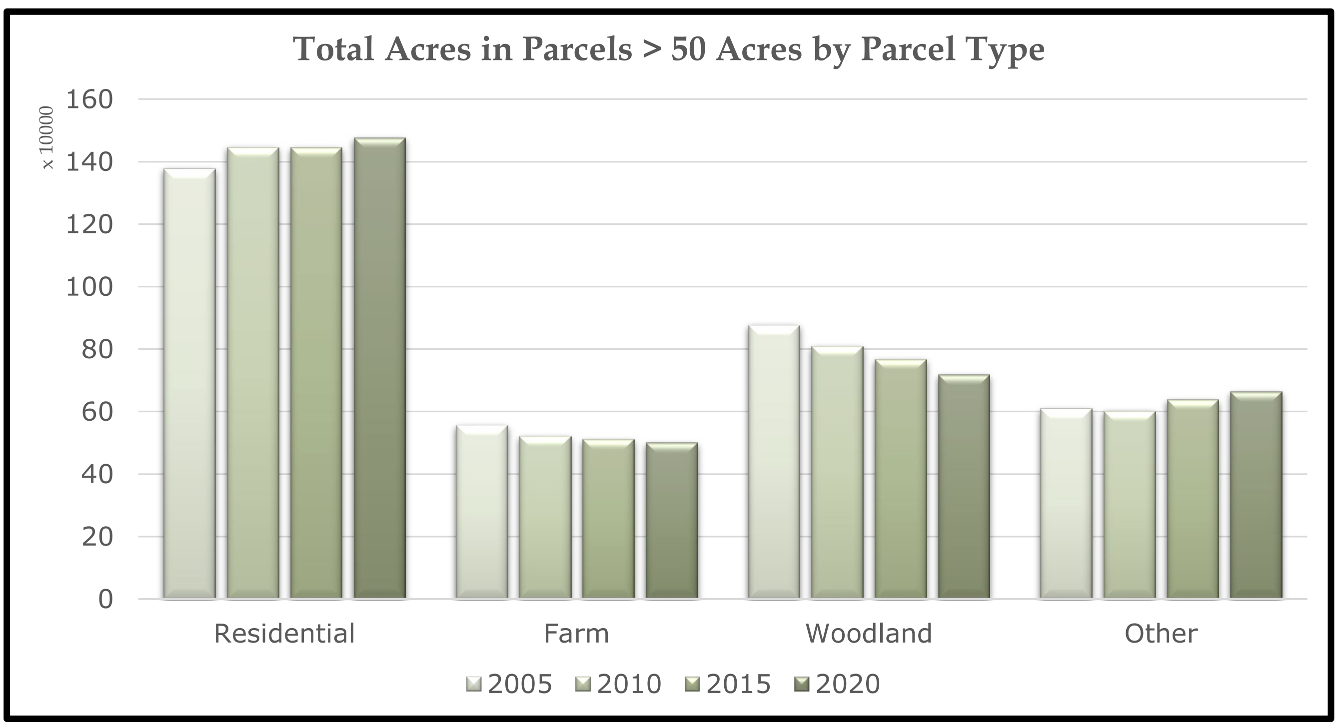


Figure 11 The number of acres in the "residential" category is increasing while "farm" and woodland" acreage is decreasing, with "woodland" acreage decreasing the fastest.

Vermont town forest census

Julie Frost[1], Cecilia Danks[1], Laura Edling[1], Kate Forrer[2], Keith Thompson[3], Elise Schadler[4]

[1]UVM RSENR, [2]VT Woodlands Association, [3]Vermont FPR Private Lands Program, [4]Vermont FPR Urban and Community Forestry Program

Town forests play a special role in forest conservation in the Northern Forest region because they are publicly managed and accessible forest parcels that contribute to forest integrity, ecosystem services and community well-being. They also serve as effective models to family forest owners of how to conduct sustainable forest management to achieve diverse conservation goals. Acquisition of new town forests often adds strategic pieces to regional conservation efforts that counteract the growing fragmentation of the Northern Forest and help sustain the forest products industry. Many communities, however, find that managing these parcels can also bring special challenges as they seek to provide diverse public demands with limited resources. For these reasons and more, town forests are identified in the Vermont Forest Action Plan as a priority landscape, and several public and private initiatives in recent years have sought to build the capacity of communities to meet such challenges. Project collaborators have identified several needs hampering these efforts: the lack of a complete inventory and key contacts of town forests, inadequate public maps and information on town forests, and uneven knowledge of community needs. The VT Town Forest Census will help fill these gaps by conducting a complete census of forests owned by VT municipalities which can be repeated periodically in the future. We will identify fixed parameters to monitor in every census, as well as novel questions that address emerging issues and capture innovation. Identifying the needs and progress of municipalities in addressing diversity, equity, and inclusion in their town forests are among the topic priority issues for this census. We will ask towns about their interest, actions and capacity-building needs regarding disabled access, incorporation of cultural history, contributions to health and economy, and meaningful land acknowledgements and accompanying actions. Additionally, we will be using the InVEST Software (The Natural Capitol Project, Stanford University) to assess the benefits of several ecosystem services. As a work in progress, this presentation will share challenges and learning to date while seeking input from attendees on what resources we should share with local communities as we reach out to them to conduct this census, as well as the highest priority questions to ask. To have good response rates, we will strive to have a short survey and will invest the time and resources to reach all communities.

Forest Management and Restoration

Vermont Seed Project

Jess Colby[1], Brooke Fleischman[2]

[1]NorthWoods Stewardship Center, [2]Intervale Center

While there is increasing demand for locally adapted native plant materials for riparian restoration projects, nurseries are unable to adequately ramp up supply to accommodate those needs. Between 2015 and 2020, work was completed by Annalise Carrington (formerly of the Intervale Center), Pete Emerson (Vermont Fish & Wildlife Department), and Fritz Gerhardt (Connecticut River Conservancy) to look at different techniques for site preparation at riparian restoration sites. The goal was to control the existing vegetation to (a) expose enough bare soil to allow for successful natural regeneration of riparian woody species and/or (b) prepare a seedbed to allow for the direct seeding of riparian woody species. Some of their main challenges were identifying seed collection locations and gathering enough seed to use in these trials.

In 2021, the Vermont Seed Project (VSP) started as a collaborative effort amongst Vermont Fish & Wildlife (VFWD), Intervale Center, NorthWoods Stewardship Center (NWSC), U.S. Fish and Wildlife Service (USFWS), The Nature Conservancy (TNC), and many others to begin collections of native tree and shrub species. In 2023, the VSP hired a statewide seed coordinator to better coordinate partners to gather, process, store, and use 22 species of native riparian shrub and tree seeds across the state for restoration purposes.

The VSP works closely with local conservation nurseries on native plant propagation and with other partners on forest restoration projects. The partnership continues their efforts with direct seeding trials alongside Vermont Fish & Wildlife as an alternative restoration approach to planting bare-root stock. We work to build out capacity by acquiring seed cleaning machines, expanding storage space, and housing a database of mapped seed source locations and phenology data. (Figure 12).

Looking to the future, the Vermont Seed Project expects to understand the demand, ramp up supply, and create more coordinated and collaborative efforts across the northeast region toward local native seed. The VSP pilot program has received support (3 years) from the VFWD and USFWS and is expected to conclude in 2025.

Our presentation will review our work-to-date, outline our plans for next season and beyond, and discuss challenges and opportunities for this work into the future.

Figure 12 The Vermont Seed Program has invested in seed cleaning machines and equipment.

Open forest ecosystems of Southern New England: Their characteristics, restoration, and importance to diversity

Tom Wansleben[1]

[1]Massachusetts Division of Fisheries and Wildlife

Open Forest ecosystems of oak & pine woodlands and savannas once covered significant areas of interior southern New England for millennia. Shaped and tended by Indigenous fire practices, these park-like ecosystems with their large but spaced overstory trees and little to no mid story, promoted a rich understory of diverse sun loving vegetation including forbs, grasses, and shrubs that in turn supported an abundance of biodiversity. The decimation of Indigenous societies followed by fire suppression policies, have led to the dramatic loss of these pyrogenic ecosystems all over the East, resulting in monumental vegetation shifts to denser multi layered forests composed of more shade tolerant mesophytic species like red maple. This loss, especially of the understory vegetation is thought to be a significant factor in the decline of the biodiversity they once supported including many specialized plants and their pollinating insect counterparts. In Massachusetts alone approximately 40% of plant and animal species listed under the Massachusetts Endangered Species Act directly benefit from fire influenced open forest ecosystems along with numerous other declining species making their restoration a conservation priority.

To address this priority, the Massachusetts Division of Fisheries and Wildlife (MassWildlife) has invested in the acquisition and landscape scale restoration of lands that once supported these open forest habitats including the development of a robust prescribed fire program (Figure 13). But before fire can be applied, the restoration of these sites often requires commercial timber harvests, mulching and herbicide applications along with a complex web of permitting. But the ecological results are often rapid and dramatic, including the return of state listed birds after decades of absence, tripling of bee species diversity and endangered plant populations going from a few individuals to some of the largest population in the state. What wasn't anticipated but celebrated is the re-connection of people to these open forest ecosystems through foraging, hunting and birding.

This talk will provide an overview of the characteristics of these open forests including where they are found on the landscape, how they are actively being restored, the positive response of biodiversity (including humans) to these efforts and the immense opportunities for much needed regional research on these forgotten ecosystems.

Figure 13 Fire is used as a restoration and management tool at Montague Plains WMA, an open forest habitat.

Planting 2 billion trees in support of climate change mitigation, biodiversity, and human well-being

Sevrenne Sheppard[1]

[1]Canadian Forest Service

In 2021, the Government of Canada launched the 2 Billion Trees Program (2BT), which aims to motivate and support new tree planting projects across the country. Over a period of 10 years, by 2031, up to $3.2 billion will be invested in tree planting efforts to support provinces, territories, third-party organizations (for-profit and not-for profit) and Indigenous organizations to plant two billion trees across Canada. Projects funded by 2BT will contribute to Canada's GHG emission reduction and net zero emissions targets. 2BT also aims to achieve several co-benefits, including long-term restoration and maintenance of forests for species at risk and other species of interest, increasing forest diversity and climate resilience, and enhancing the well-being of Canadians for generations to come. Over the past two years, 2BT has been working to develop an approach to measuring the impacts of funded projects on biodiversity and human well-being. This presentation will give an overview of the program's progress and lessons-learned in the first two years of planting, and will discuss plans for measuring biodiversity and well-being outcomes (Figure 14).

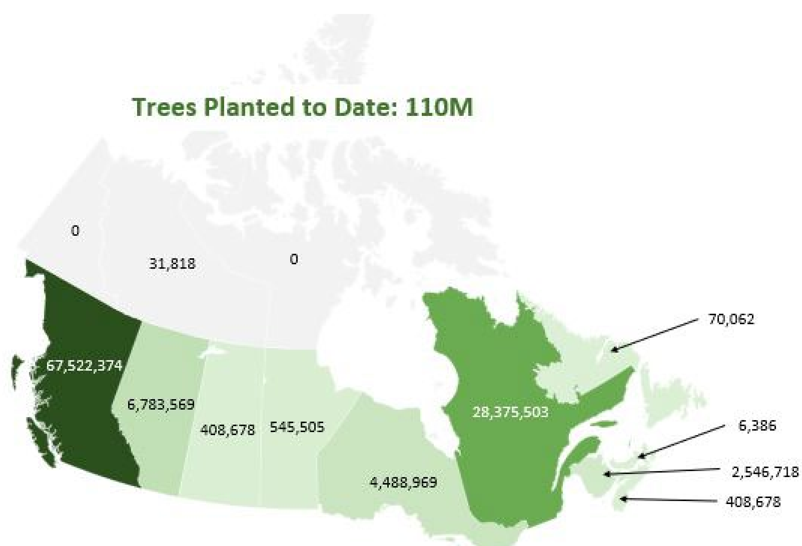


Figure 14 The program has planted 110 million trees to date, which includes 220 species at 2,900 sites with over 47% of proposals for Indigenous-led (21%) and urban (26%) projects.

Tree regeneration and carbon replacement in forests of the northern US

Chris Woodall[1], Anthony D'Amato[2], **Lucas B. Harris**[2]

[1]USDA Forest Service Research and Development, [2]University of Vermont

Natural regeneration in forests across the US is threatened by a confluence of factors including climate change, heavy browsing, changes to disturbance regimes and non-native pests and pathogens. Tree regeneration patterns shape forest carbon dynamics by determining the composition of future forests, which suggests that threats to natural regeneration may diminish the capacity of forests to replace carbon lost through tree mortality. Yet, the potential implications of tree regeneration patterns for future carbon dynamics have been sparsely studied. We used field plots from the Forest Inventory and Analysis (FIA) program to investigate how the composition of existing tree regeneration may influence future carbon storage for forests across the northeastern and midwestern US, leveraging a recently-developed method to predict the likelihood of sapling recruitment from seedling abundance within the six seedling height classes monitored under FIA's detailed Regeneration Indicator protocols. A model of live aboveground tree carbon storage was developed and used to compare predicted carbon storage based on seedling composition to predictions based on existing tree composition. Plots predicted to lose carbon storage based on seedling composition tended to be on steeper and south-facing slopes, be located farther east, have higher current carbon storage and be within maple/beech birch and oak/hickory forest types. Our results demonstrate the need to consider tree regeneration through the lens of carbon replacement in order to develop effective management strategies to secure long-term carbon storage.

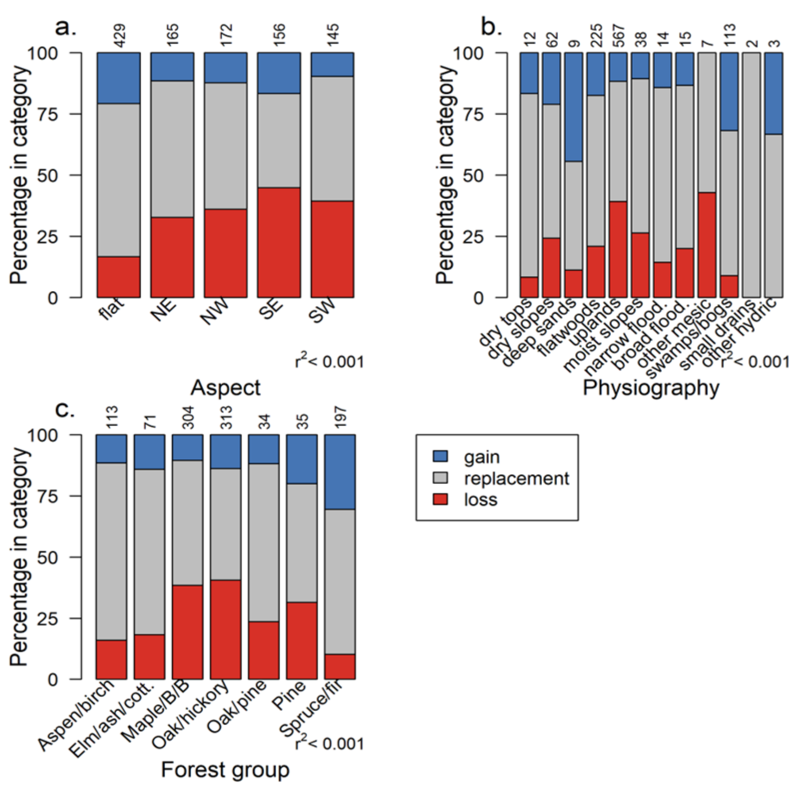


Figure 15 Carbon storage loss was greatest on steeper and south-facing slopes; outlook is worst in maple/beech/birch and oak/hickory, best in spruce/fir

Climate Adaptation

Connected Forests for Climate Adaptation: Updates to Vermont Conservation Design

Robert Zaino[1], **Andrew Wood**[1], Shelby Perry[2], Jens Hilke[1], Gus Goodwin[3], Alexandra Kosiba[4]

[1]VT Fish & Wildlife Department, [2]Northeast Wilderness Trust, [3]The Nature Conservancy, [4]The University of Vermont

For the last two years, the Vermont Fish & Wildlife Department and partner organizations have been working to update the Habitat Blocks Dataset, an integral building block for Vermont Conservation Design. Vermont Conservation Design is a scientific vision identifying the highest priority lands and waters needed to sustain Vermont's biodiversity into the future. Using the University of Vermont's high-resolution LiDAR-derived landcover datasets together with other data products has allowed us to re-map all Habitat Blocks statewide, now including the many connecting lands along the margins of Habitat Blocks that stitch together the network of connected forestland across the state (Figure 16). Join us for a preview of this work and a discussion on how these connecting lands serve our climate adaptation aspirations.

a)

b)

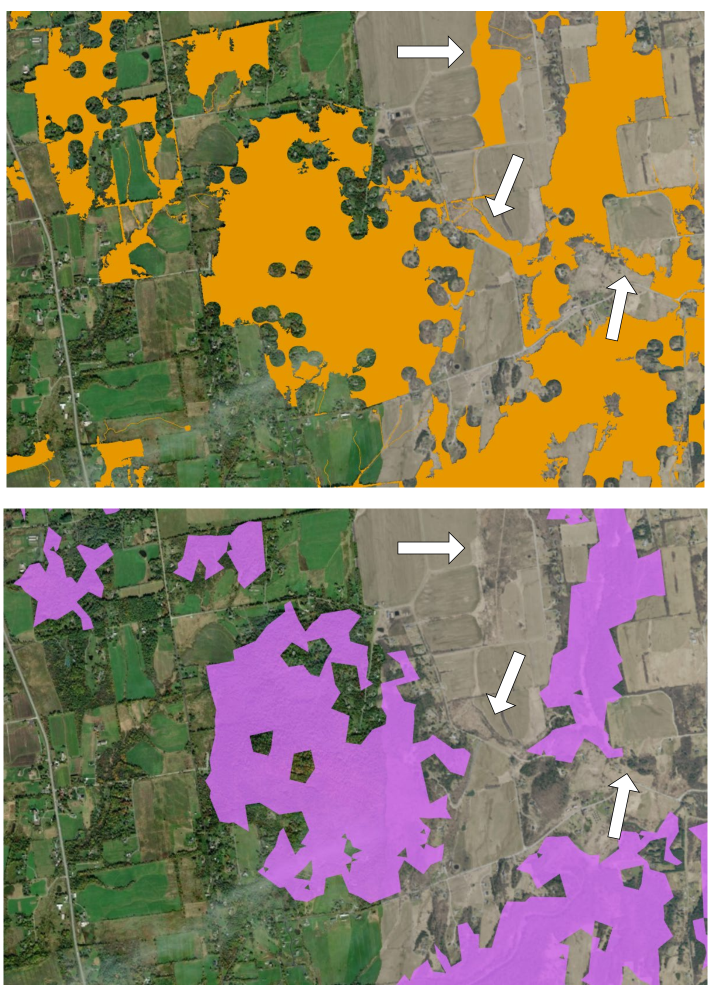


Figure 16 The Habitat Blocks Dataset updates landcover datasets that better detects habitat block connections (a). Older datasets do not detect housing developments as well (b).

Using Habitat Restorations to Test Climate Change Adaptation Strategies

Chris Nadeau[1], Randall Hughes[2], Abe Miller-Rushing[3], Nicholas Fisichelli[1], Phil Colarusso[4], Eric Schneider[5]

[1]Schoodic Institute at Acadia National Park, [2]Northeastern University, [3]Acadia National Park, [4]Environmental Projection Agency, [5]Rhode Island Department of Environmental Protection

Dozens of climate change adaptation strategies have been proposed in the literature, and practitioners are already implementing many of these strategies worldwide. However, very few strategies have been tested empirically to determine if and when they will be effective. Hence, conservation agencies could be investing significant resources in strategies that fail to produce the desired results or cause harmful unintended consequences. Rigorous tests of climate change adaptations strategies are necessary to support conservation under climate change.

In this presentation we will suggest that rigorous tests of climate change adaptation strategies are likely lacking because of a tradeoff between the time and resources necessary to implement these tests, and the urgent need for action. We will highlight limitations with current recommendations that call for implementing a single action, monitoring for effectiveness, and adapting management practices as necessary. We will then suggest an alternative approach where management actions are designed as experiments to test climate change adaptation strategies without delaying action. Specifically, we will suggest that practitioners employ multiple climate change adaptation strategies simultaneously following the tenets of experimental design, including: replication, randomization, and control treatments. Using this experimental approach will not only provide the evidence necessary to improve future management, it also has many other benefits, including: (1) increasing resilience of the managed system through the portfolio effect, (2) providing tests of our knowledge in climate change biology, (3) helping practitioners and funders overcome the fear of failure by learning from failed actions, (4) resolving stakeholder conflicts, and (5) providing opportunities for highly effective science and management communication. We will conclude by providing two case studies to demonstrate the benefits of taking an experimental approach to test climate change adaptation strategies during ecological restorations: (1) a test of assisted gene flow on mountain summits (Figure 17) and (2) a test of multiple methods to slow the spread of invasive species in wetlands.

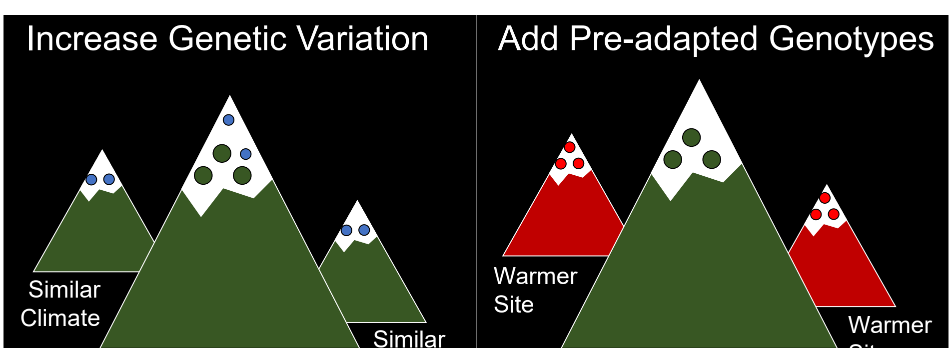


Figure 17 Climate change adaptation strategy includes assisting gene flow on mountain summits by adding pre-adapted genotypes.

Climate-friendly forest management on AMC's Maine Woods Initiative

David Publicover[1]

[1]Appalachian Mountain Club

The Appalachian Mountain Club's Maine Woods Initiative is the most ambitious undertaking in the Club's 150-year history. Begun in the early 2000s as an effort to integrate land protection, backcountry recreation, biodiversity conservation, sustainable forestry, and community partnerships, MWI now encompasses about 114,000 contiguous acres in the 100-Mile Wilderness region of Maine, nearly all of which is encumbered by multiple conservation easements. Through a combination of reserves and conservative timber management, AMC is working to restore these heavily harvested former industrial lands to a more natural, mature, and structurally complex forest with higher value for biodiversity, carbon storage, and climate resilience. Currently about 28% of the ownership is in permanent ecological reserves, another 14% is other no-harvest protection zones, and 4% is nonforested, leaving 54% available for timber management. AMC's management is certified by the Forest Stewardship Council as part of The Nature Conservancy's group certificate, and our conservative approach has been compensated through three verified carbon offset projects.

The presentation will discuss AMC's forest management and silvicultural approach, how we are incorporating "climate-friendly" practices into our management, how 2010 and 2020 inventories show significant early progress towards our goal of restoring a more mature forest, the extensive research and monitoring activities taking place across the property, and how the proceeds from carbon offset projects are being reinvested in support of AMC's "Net Zero by 2050" organizational goal (Figure 18.

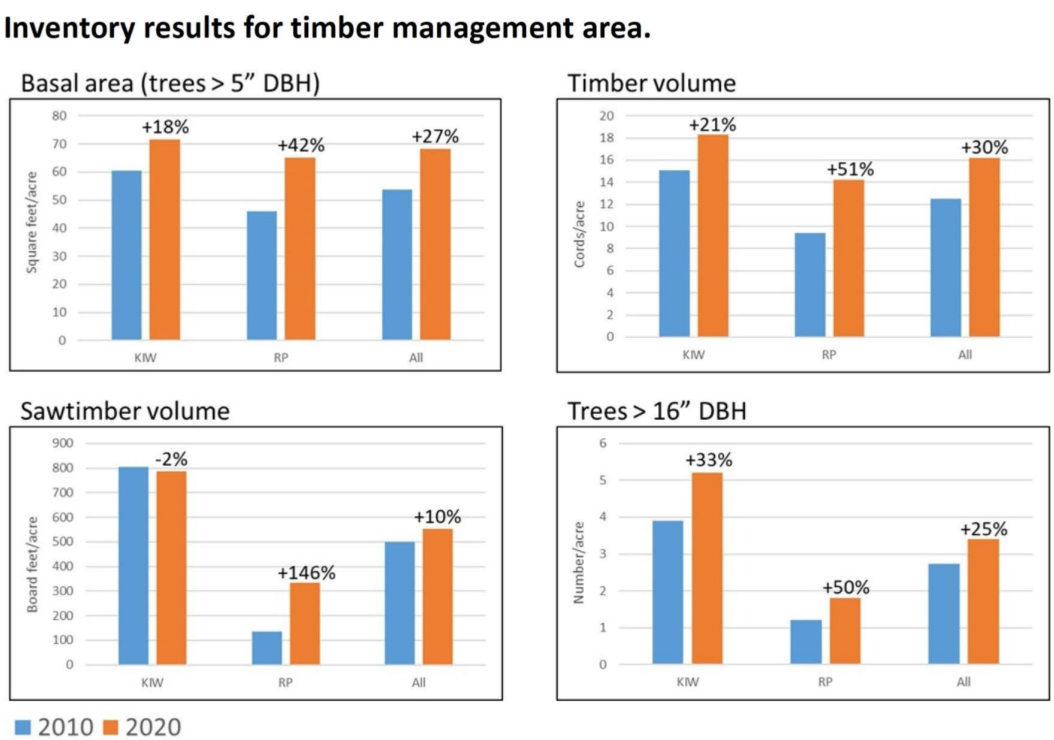


Figure 18 Comparison of 2010 and 2020 timber inventories showed increases of between 10% and 30% in several measures of forest maturity. Carbon stocking is estimated to have increased 17%. Carbon inventories in 2011 and 2021 showed carbon stocking increased nearly 19% (about 2.2 mT CO2e/acre/year).

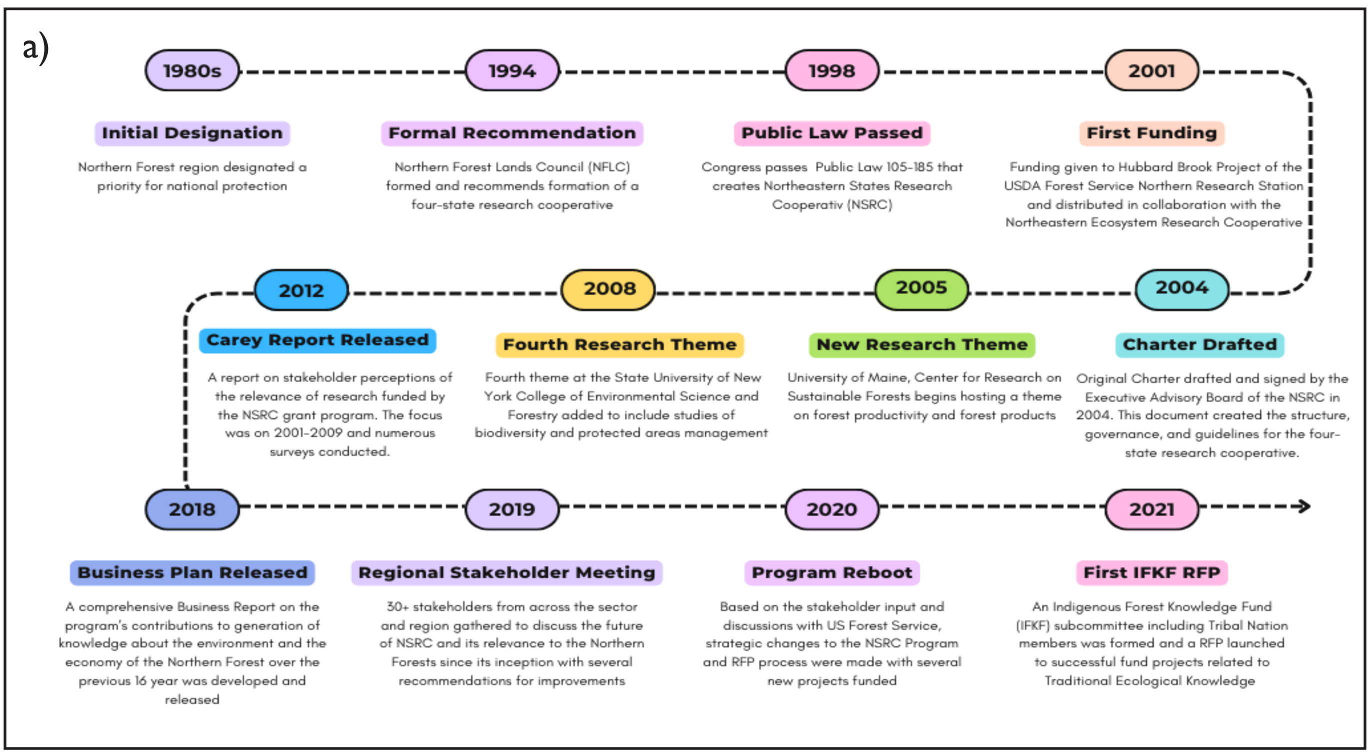
Northeastern States Research Cooperative (NSRC)

NSRC Overview

Aaron Weiskittel[1], **Dan Day**[2]

[1]University of Maine, [2]U.S. Forest Service

Aaron Weiskittel, University of Maine NSRC director, and Daniel Dey, USFS, will present on the current and future outlook for the Northern States Research Cooperative, a competitive grant program for Northern forest research supporting cross-disciplinary, collaborative research in the Northern Forest (Figure 19). The current RFP will result in nearly $5 million in 2024 for research that addresses the importance of the Northern Forest to society and the need to work collaboratively with the people who live within its boundaries, work with its resources, use its products, visit it, and care about it.



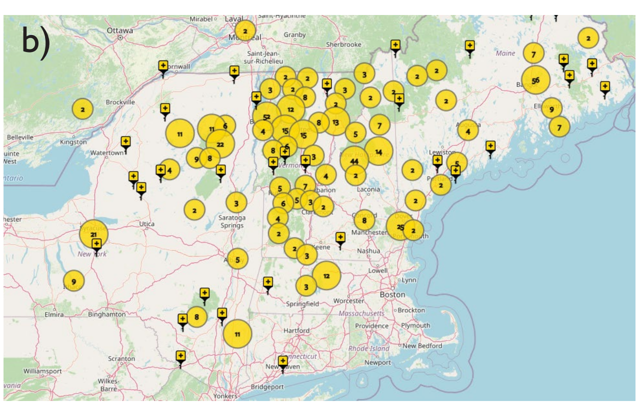


Figure 19 History of NSRC (a) and map with locations of funded projects (b)

Implementing forest adaptation options for Northern Forest ecosystems

Tony D'Amato[1]

[1]University of Vermont

Climate change and increasing prevalence of non-native invasive insects and diseases are some of the most significant challenges facing forest managers in sustaining ecosystems across the Northern Forest region. This project will increase the application of adaptation strategies to enhance forest resilience to climate change and invasive pest and disease impacts, while also sustaining critical ecosystem services, including wildlife habitat, carbon storage, and local forest-based economies.

NSRC researchers will evaluate outcomes and effectiveness of already implemented adaptation strategies and partner with resource managers to produce site-tailored recommendations on best practices for anticipated impacts of climate change and invasive species. This project uses a network of adaptation experiments and demonstrations in Maine, New Hampshire, New York, and Vermont on more than 30 sites to better understand the ability of forest adaptation strategies to address emerging forest health and climate change impacts. Researchers will measure forest structural, compositional, and functional outcomes of these strategies at these sites to document forest management approaches that provide the greatest adaptation potential for northern hardwood, mixedwood, and spruce-fir ecosystems (Figure 20). Through partnerships with federal, state, Tribal, private, and NGO forestry stakeholders, researchers will develop outreach materials, such as pamphlets, webpages, webinars, and workshops that identify sitetailored, best adaptation practices for these key forest types in northern New England and New York.

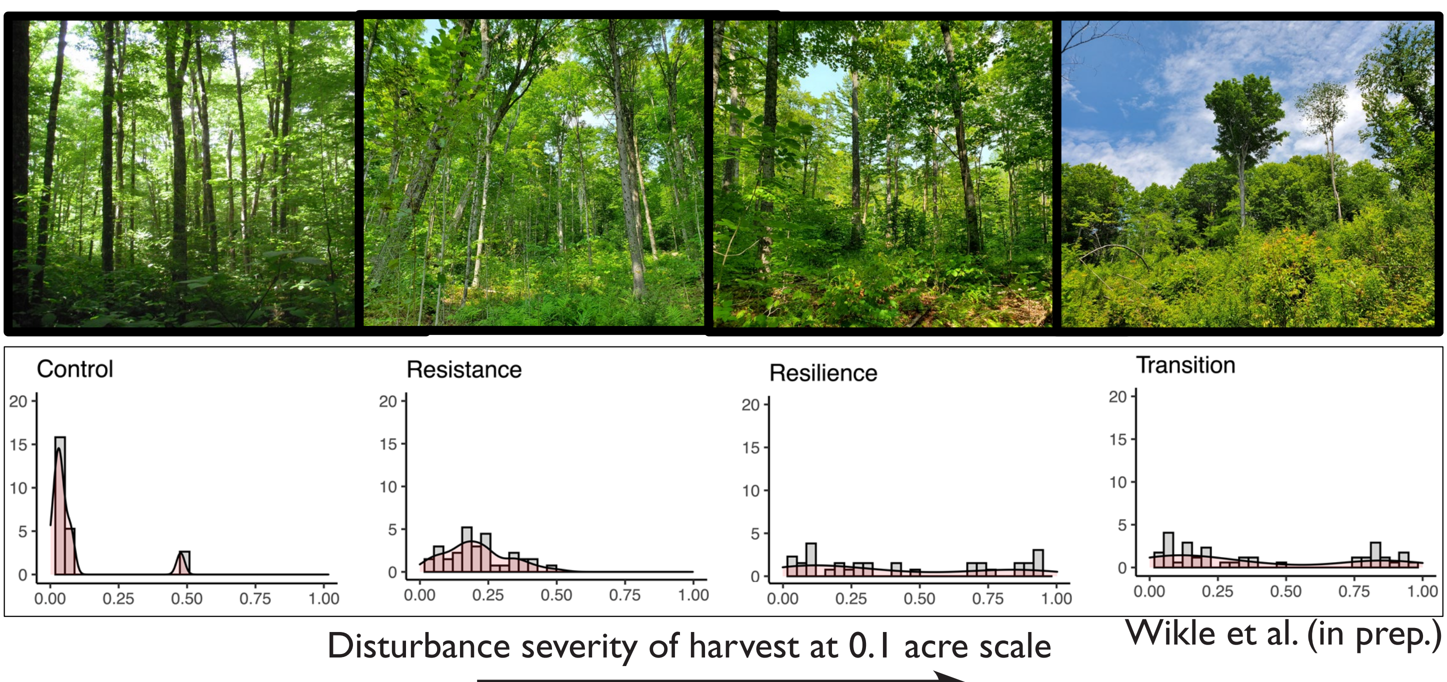


Figure 20 Functional outcomes of adaptive silviculture: spatial variability in harvest severity and adaptation pathways.

Assisted Migration: A viable silvicultural technique for facilitating adaptation of northern Forest tree species toa warmer and drier future world?

Matt Vadeboncouer[1]

[1]University of New Hampshire

Greater frequency and intensity of drought in the Northern Forest region will likely impact survival, growth, and reproduction of different tree species under future climate conditions. At the same time, the rate at which climate is changing in the region is outpacing tree species' ability to migrate into future suitable habitats. Both of these phenomena threaten sustainability of the region's forest ecosystems and communities. Forestry assisted migration, the intentional movement of climate-adapted tree species into anticipated future suitable areas outside their current range, may be a useful silvicultural tool for promoting future resilient forests.

NSRC researchers and local stakeholders in the four-state region will evaluate the capacity of ten assisted migration tree species to acclimate to new environments and drought in a periodically drier, warmer future Northern Forest. They will also quantify how morphological, anatomical, and physiological tree species traits show plasticity, or flexibility, to handle drought and the potential for particular traits to be indicators of seedling success.

The research builds on an existing project, Adaptive Silviculture for Climate Change (ASCC), which initiated an assisted migration experiment across a network of seven sites throughout the Northern Forest. At the main study site, Second College Grant in New Hampshire, researchers will conduct a drought experiment to assess seedling acclimation potential and trait plasticity (Figure 21). Measurements will be collected at the other six ASCC sites to evaluate seedling responses across broader temperature and precipitation gradients at the landscape scale. The results will inform guidelines for selecting suitable assisted migration species as part of climate change adaptation strategies to promote future resilient forests.

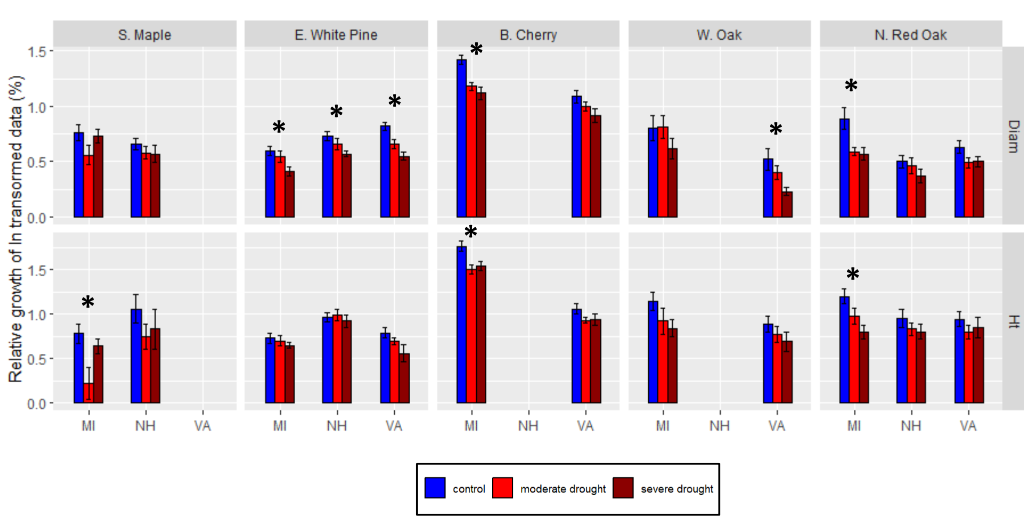


Figure 21 Droughted plants grew less and prioritized height over diamter growth. Asterisks denote significant treatment effect within species and ecotype. Error bars are +/- 1SE.

Evaluating the efficacy of Audubon's bird-friend maple: Can managing sugarbushes for birds provide benefits to biodiversity, ecosystem services, and forest resilience?

Steve Faccio[1]

[1]Vermont Center for Ecostudies

Maple sugaring is experiencing rapid growth across the Northern Forest in the scale of operations, acreage impacted, and number of people involved. As a result, it is becoming increasingly important to better understand how sugarbushes can be managed to benefit both maple production and biodiversity conservation.

Maple syrup can be produced from forests that are managed in dramatically different ways. The long-term sustainability of maple sap production is entirely contingent on healthy forests, but our knowledge is limited on how the complex drivers of increased maple sap production intensity, differing management strategies, and climate change will affect biodiversity, ecosystem services, and overall ecological health of sugarbushes. By conducting field surveys of biodiversity and ecosystem service metrics across a gradient of sugarbush production and management intensities, NSRC researchers will pioneer this knowledge base and develop tools and policies that provide sustainable sugarbush management guidelines that are relevant across the Northern Forest landscape. This will result in updated guidance for sugarmakers and specific revisions to the bird-friendly maple management guidelines in order to achieve the desired benefit for bird populations (Figure 22).

Figure 22 Coarse woody material is an important component of forest bird habitat that should be left in place as part of sugarbush management guidelines.

Working Sessions

Assessing the potential of a management toolbox for Northeastern alpine ecosystems

Facilitators: Jordon Tourville (Appalachian Mountain Club) and Chris Nadeau (Schoodic Institute)

The following is a summary of the discussion from the workshop “Assessing the potential of a management toolbox for Northeastern alpine ecosystems” held at the Forest Ecosystem Monitoring Conference, 14 December 2023. We had a great group of approximately 32 people, from 3 states, and a diversity of organizations and job types (see figures below for more information and word clouds from poll responses - note: not all attendees answered every question).

The group identified **climate change, invasive species, and impacts from recreation** as the primary current stressors in northeastern alpine areas. There are many current efforts to minimize impacts from these stressors, but the most common themes included **education, recreation management, and restoration/trail work.**

In the future, people expect the current major stressors (i.e., climate change, invasive species, and recreational impacts) to get worse. For example, reduced snowpack due to climate change could result in higher vegetation and soil impacts from winter recreation. **Education, recreation management, and restoration/trail work were common management ideas for these future stressors.** However, it was also recognized that we might need to modify these management approaches to meet new challenges. For example, winter recreationists might be a different audience than summer recreationists, and therefore require different messaging and engagement strategies for education. Assisted migration and genetic research are also ideas for future management.

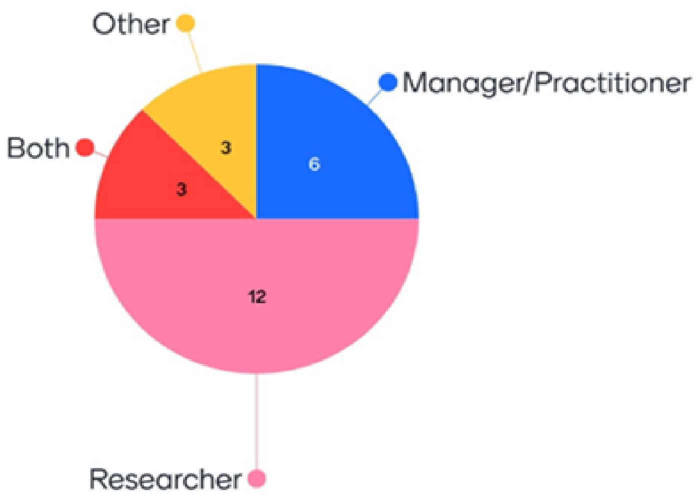
The group also identified some novel future stressors, such as **upward expansion of some mammals that could impact plant communities, decreases in the population size and distribution of plants and animals from warming, or soil warming** that could affect the soil microbiome and ultimately reduce primary production. These novel stressors pose unique challenges for management. **For example, conserving populations of some plants could require banking seeds or augmenting populations with warm-adapted seeds or seedlings. However, some in the group also recognized that novel management approaches, such as augmenting populations, are controversial because they could have unintended consequences.**

The group identified a series of resources and next steps that could help address current and future management challenges, including:

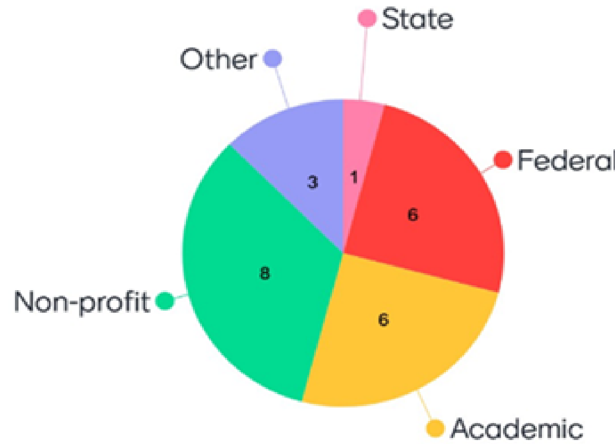
- An archive of relevant reports and papers on alpine ecology and stewardship in the northeastern US, and a summary literature of the existing research.
- A regular venue for practitioners and academics to meet to discuss alpine ecology and stewardship. The Waterman Fund hosts the Northeast Alpine Stewardship Gathering approximately every other year, but meetings in off years would be extremely useful.
- Coordinated monitoring of key aspects of alpine ecology, such as plant genetics and the soil microbiome.
- Institutionalized stewardship that moves away from volunteer education staff.

Responses to online poll questions:

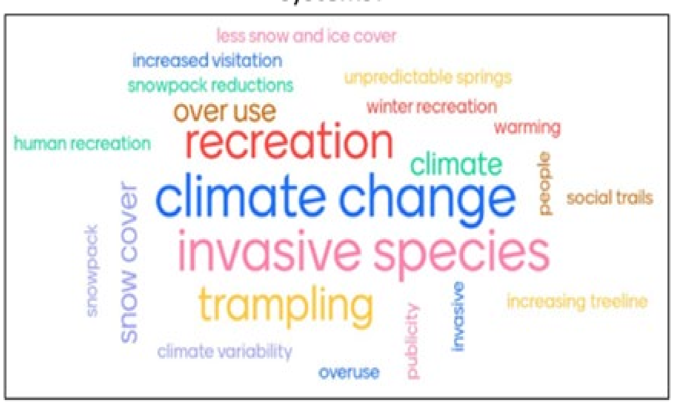
Do you consider yourself primarily a:



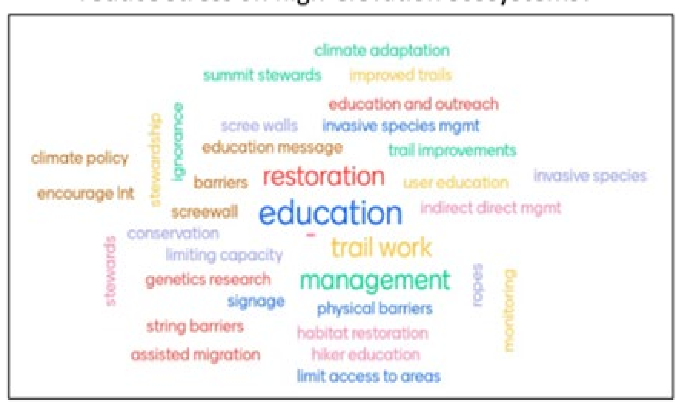
What type of organization do you work for?



What stressors are currently impacting high-elevation systems?



What management actions are currently being taken to reduce stress on high-elevation ecosystems?



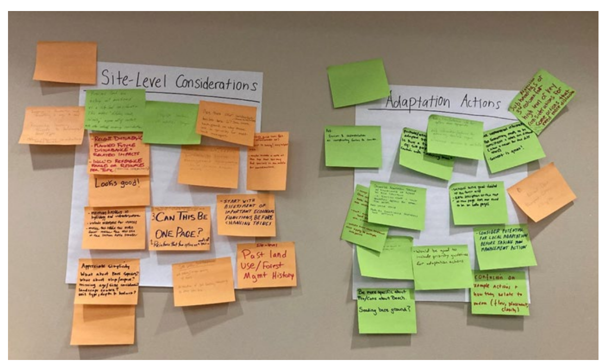
What resources or knowledge could we provide that would improve the health or management of high-elevation ecosystems

Implementing forest adaptationstrategies for northern hardwood, mixedwood, and spruce-fir forests

Facilitators: Samantha Myers (Northern Institute of Applie Climate Science/Iniversity of Vermont) and anthony D'Amato (University of Vermont)

The uncertainty around the impacts of climate change, invasive species, and extreme weather events poses a significant challenge to sustaining forest ecosystems in the northeast. In response to this challenge, numerous field applications and experiments have been developed over the past decade that are testing different adaptation strategies to maintain diverse forest values in the face of changing environmental conditions. This working group session presented a forthcoming managers guide based on the outcomes of this work and broader manager input that outlines best adaptation practices for northern hardwood, mixedwood, and spruce-fir forests. The session facilitated discussion among 70 forestry and natural resource professionals and research scientists to improve the final version of the guide and garner input on adaptation strategies being used by the broader management community to address climate change impacts to these key ecosystems.

Participants thought the content and flow of the guide would be helpful in adaptation planning at the site-level, but also saw areas where more details and reference material could be included to better understand relative climate risks, costs, and operational considerations for adaptation actions and in case study examples. Outcomes of this session are informing the design of a managers guide to adaptation and associated web resources highlighting adaptation case studies to enhance the region's capacity for implementing forest adaptation strategies.



Regional snow and mountain weather observation networks

Facilitator: Joshua Benes (University of Vermont) and Erika Rowland (Forest Stewards Guild)

Overview

The North Eastern Snow Study (NESS) is an initiative to provide researchers, managers, and forecasters with critical data needed to better predict spring flooding events as well as the potential for drought; to enhance understanding of how changing snow dynamics will affect winter-based economies such as snow recreation and forestry; to make quality real-time data on snow conditions available to recreationists across the region; and to improve understanding of how changing snowpack dynamics are impacting ecosystem dynamics. This project is funded through federally appropriated funding by the USDA, Natural Resource Conservation Service (NRCS) which allocated funding to University of New Hampshire, University of Vermont, Schoodic Institute, Appalachian Mountain Club, Forest Stewards Guild, and New York State Mesonet.

Josh Beneš and Erika Rowland convened the working group to gather input as a part of NESS's stakeholder engagement phase, an early stage of the project. The next phases include partnership development and on-the-ground site selection, followed by development of a public report detailing priority sites, partnership agreements, and developing data-sharing and dissemination plan as well as implementation plans. Finally, NESS will be handed to NRCS for implementation.

The discussion centered around the 3 questions; 1) are there additional objectives the network should adopt, 2) which metrics should each station collect, and 3) what are the network design's must-haves, should-haves, and would-be-nice-to-haves? The group encouraged NESS to use existing sites and infrastructure as much as possible, establish sites that account for a variety of conditions, incorporate student and citizen science efforts, and link climate data to ecological, remote sensing, and social/recreation-related metrics where possible. The group also stressed the importance of a well-staffed network, using a data management system that is well maintained.

Josh also shared updates about the formation of the Northeast Network of Mountain Observatories, the subject of a Working Session that he led during the 2022 FEMC Annual Conference. This observatory network to combine Whiteface Mountain Observatory and Mount Washington Observatory, standardizing data with a shared web portal, with regional stakeholders coordination with potential for integration into international high elevation climate monitoring and modeling objectives. Sites incorporated into this network will be the Summit-to-Shore Environmental Observation Network, a series of 22 climate monitoring sites from Lake Champlain to the Northeast Kingdom, VT, to study snow dynamics across elevation gradients. The Summit-to-Shore sites are funded by Cold Region's Research and Engineering Laboratory (CRREL) led by Arne Bomblies and Beverly Wemple, present for the discussion. Josh has also been collaborating with the Atmospheric Sciences Research Center (ASRC) on Whiteface Mountain, NY. Paul Casson, Site Operations Manager for ASRC, was also present for the discussion.

Discussion

Question 1: What other objectives (beyond spring flooding / potential for drought, winter-based economy impact, data for recreationalists, climate monitoring/ecological change) should we be considering? Which ones would you prioritize?

Responses:

- Connect climate modeling and data with other studies (social issues, plant migration, wildlife dynamics, and forest health monitoring, etc)
- Remote sensing calibration and validation
- Enhancements for winter recreational use and planning
- Better understanding flooding and other seasonal dynamics

Question 2: What other monitoring variables should be considered at each monitoring station? How often should they collect data? How should data be shared?

Data being considered: Temperature (2m & 9m), wind (10m; Sonic and Propeller), relative humidity, solar insolation, precipitation, snow depth, snow water equivalent, pressure, soil and moisture at various depths.

Responses:

- Wind speed and direction
- Soil moisture and temperature at various depths.
- Solar radiation and atmospheric pressure measurements.

Question 3: Network design: What are the must-haves, should haves, and would-be-nice-to-haves?

Responses:

Must-haves:

- Well-maintained data management infrastructure
- Staffing for maintenance and data management

Should-haves:

- Partner with existing meteorological groups for operational support
- Diverse stakeholder engagement

Would-be-nice-to-haves:

- Guidance from statisticians for optimal site placement
- Collect high-frequency data to capture rapid changes to ensure relevance for real-time applications
- Use existing sites to avoid redundancy and incorporate historic data and additional metrics
- Pilot test new sites prior to full-scale implementation
- Cluster sites to capture variability, which could be more informative than widespread, sparse sites
- Locate snow monitoring sites under the forest canopy as well as in openings
- Locate sites relative to population centers, watersheds, critical water resources, or ecologically sensitive areas for broader data applicability and relevance
- Consider existing gaps in the regional monitoring network to ensure comprehensive coverages
- Establish sites on university properties to facilitate student engagement and research
- Coordinate efforts across institutions, involve graduate students
- Incorporate citizen science efforts
- Share data in ways that is accessible for both technical and non-technical users
- Develop outreach programs that encourage data usage and a deeper understanding of climate data

Creating a rapid response tree rescue network

Facilitators: Elissa Schuett and Alison Adams (FEMC, University of vermont)

Overview

A working session was held during the FEMC Annual Conference to discuss the need for and creation of a rapid response network to tree mortality rescue efforts across the FEMC program region. The session was led by Elissa Schuett and Alison Adams of FEMC as part of a scoping project that was conducted in 2023 using emerald ash borer as a test example. Attendees of the working session were not specifically a part of the scoping project, but were familiar with processes used at various agencies across the region and brought a wealth of knowledge and expertise to the conversation.

The original goal of the session was to discuss how a rapid response network could be formed and activated if a new threat to tree health emerges. During the discussion, participants identified networks and processes that already exist within some states and described a number of barriers that exist and would limit the success of a regional network. Some gaps and future opportunities were also identified for consideration. It was noted that there was not a strong need for a regional response.

Current approaches

Many states have procedures in place to respond to tree mortality threats. These procedures differ among states and do not readily cross state borders. New York uses the National Incident Management System to guide responses to incidents. The system uses Incident Command Systems (ICS) and multiagency coordination groups (MAC groups) to guide when a response should be activated, who responds, and what is done. The processes and procedures established in New York provide the ability to respond to incidents as they arise. Maine also has response plans and funding in place to support actions as needed. However, Connecticut and Rhode Island do not have a structured response plan. Massachusetts tried to implement a plan in response to spotted lantern fly, but it was not successful and abandoned.

In addition to state response systems, all of the FEMC states are also a part of the Northeastern Forest Fire Protection Commission (commonly called the Northeast Compact). The NE Compact provides a mechanism to provide U.S. member states and Canadian provinces with resources, information, and technology to respond to forest fires through mutual aid activities when a single state would not be capable of responding alone. The structure of the NE Compact promotes the transfer of supplies, personnel, technical assistance, and other resources across state and provincial boundaries. In addition to state representation, there are also federal agencies with representation, including the Bureau of Indian Affairs, U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. National Park Service.

While the NE Compact is largely focused on forest fire response, included within the structure is a Forest Health Working Team that is focused on insect and disease outbreak response. Many of the members of this team from FEMC states are on the FEMC Steering Committee.

Characteristics of response plans that facilitate or limit success

The response systems in each state are variably successful in responding to forest health threats.

The programs that have the most success have key commonalities. One noted factor is ensuring the people who are part of the emergency deployment have the experience and knowledge to fill the role they are assigned to. Subject matter experts should be a part of the deployment team. One participant in the working session mentioned that sometimes external experts are contracted to work with the team for this reason.

It is also important for relationships to exist before the response is needed. Identifying people outside of the base network can be a challenge. Creating lists of certified consultants in advance can contribute to the ability to quickly build the network. Maintaining and building relationships before a response is needed is also important. Without the relationships in place, it is hard to activate a network during an acute event.

While some plans and processes exist that provide opportunities to manage a threat to tree health, there are still a number of barriers that slow or limit responses:

- Staff time available to transition from other work onto a response team is a key limitation.
- Silos between agencies, and sometimes within, limit communication and do not allow for a coordinated response that efficiently uses resources.
- Direct connections to landowners are not always established or maintained, which also slows communication and response. Extension offices often have well-established networks and communication routes that should be tapped into by agencies to improve this flow of information.
- The uniqueness of each event contributes to the challenge of creating a general response plan.
- The regulatory authority can also add to the complexity of rapidly responding to an event because approvals may need to flow through specific channels.

Establishing plans and procedures in advance of a need for a tree health response will aid in the opportunity to quickly respond to acute events. However, there will likely often be barriers that slow the response. Due to these complexities and considering the pre-existence of response structures, it is unlikely that a regional effort would be successful. State management of communication and response effort will continue to be the appropriate approach.

Next Steps for FEMC

Opportunities exist to improve communication or implement action plans in response to tree mortality events. However, the response plans in place are largely coordinated by state governments as well as through the Northeast Compact. FEMC is not positioned to further contribute to state response processes. FEMC can facilitate the transfer of information across the region and improve communication channels as information is conveyed to FEMC.

Poster Session

A poster session was held in-person during the event. Posters are included here that were made available.

1. Alpine plants as a model system for understanding biodiversity dynamics in a warming world: Integrating genetic, functional, and community approaches

Jacquelyn Gill[1], Caitlin Mcdonough-MacKenzie[2], Jose Meireles[1], Isaac Overcast[3], Andrew Rominger[4]

[1]University of Maine, [2]Bennington College, [3]California Academy of Sciences, [4]University of Hawaii

2. Assessing Vermont's conservation strategy: Safeguarding biological hotspots in high-priority interior forests

Meryl Callaway[1]

[1]University of Vermont

3. Assessment of smoke-influence and regional trends of organic carbon concentrations in cloud and rain water samples

Christopher Lawrence[1], Arachana Tripathy[1], Paul Casson[1], John Campbell[2], James Shanley[3], Haider Khwaja[4], Mirza Hussain[4], Dan Kelting[5], Liz Yerger[5], Sara Lance[1]

[1]SUNY Albany, [2]U.S. Forest Service, [3]USGS, [4]Wadsworth Center, [5]ADK Watershed Institute

4. Bringing genomics to the field: An integrative approach to forest restoration

Anoob Prakash[1], Stephen Keller[1]

[1]Department of Plant Biology, University of Vermont

5. Carbon dioxide removal by managing forests under natural disturbances in the Northeastern U.S.

Mark Ashton[1], Mark Ducey[2], Mark Bradford[1], Sara Kuebbing[1]

[1]Yale University, [2]University of New Hampshire

6. Developing a data-driven tool to advance bird and pollinator habitat evaluation and conservation in Vermont's working landscape

Cassandra Wolfanger[1], Maragaret Fowle[1]

[1]Audubon Vermont

[7. Establishment of a new white oak common garden on the Green Mountain National Forest]

Paula Murakami[1], Laura Dewald[2], Dana Nelson[3], Chris Maier[3]

[1]USDA Forest Service, Northern Research Station, [2]University of Kentucky, [3]USDA Forest Service, Southern Research Station

[8. Genomic offset modeling for climate-smart seed conservation in red spruce]

Anthony D'amato[1], Matt Fitzpatrick[2], John Buttnor[3], Stephen Keller[1]

[1]University of Vermont, [2]University of Maryland, [3]USDA Forest Service

9. Incorporating tree genetic variation into forest monitoring: Spatial genetic analysis of northern red oak (*Quercus rubra*) from a study site in southern Maine USA

Steven Travis[1], Sienna Matregrano[1], Greg Zogg[1]

[1]University of New England

10. Northeast Silvicultural Library

Anthony D'Amato[1], Jill Levine[1]

[1]University of Vermont

[11. Northeastern forest climate change exposure mapping]

Lukas Kopacki[1,2], Jen Pontius[1,3], Anthony D'Amato[3], Jim Duncan[4]

[1]FEMC, [2]ArborVox, [3]University of Vermont, [4]VT FPR

[13. Northeastern Forest Inventory Network]

James Duncan[1]*, Emma Tait[1]*, Nancy Voorhis[1], Alexana Wolf[1], Soren Donisvitch[1], Jennifer Pontius[1], Clark Cooper[1]*

[1]FEMC, *No longer with FEMC

[12. Recreational impacts on facets of forest health]

Soren Donisvitch[1], Alison Adams[1], Matthias Sirch[1], Elissa Schuett[1], Larissa Robinov[2], Jerome Lee[1], Jennifer Pontius[1]

[1]FEMC, [2]New Hampshire Division of Forests & Lands

[13. Remote sensing technologies and the monitoring and management of subalpine summits, Acadia National Park]

John Daigle[1]

[1]University of Maine

14. Select species of concern, but an overall health northeastern forest after the 2023 forest health monitoring season

Jacob Vitale[1], Alison Adams[1], Soren Donisvitch[1], Jerome Lee[1], Ben Porter[1], Elissa Schuett[1], Matthias Sirch[1], Nancy Voorhis[1], Alexana Wolf[1], Jen Pontius[1]

[1]FEMC

15. Small forest owner's engagement with a carbon sequestration effort in Northeastern U.S.

Frederick Pond[1]

[1]Vermont Forestland Owner

16. Summit-toShore snow observatory network in Vermont

Katherine Hale[1], Arne Bomblies[1], Beverley Wemple[1], James Shanley[2]

[1]University of Vermont, [2]USGS

17. The Cotton Brook landslide: Effects on water quality and macroinvertebrate community health

Aaron Moore[1]

[1]State of Vermont

18. The Ecological Scorecard project: Monitoring ecological indicators in the Adirondack Park, NY

Natasha Karniski-Keglovits[1], Stacy McNulty[1]

[1]SUNY ESF Adirondack Ecological Center

19. Thermal calendars to inform maagement in a changing climate

Kerissa Fuccillo Battle[1], John Daigle[2], Anthony D'Amato[3], Toni Lyn Morelli[4], Nathan W. Siegert[5], Talbot Trotter[5], Aaron weed[6], Theresa M. Crimmins[6]

[1]Community Greenways Collaborative, [2]University of Maine, [3]Unviersity of Vermont, [4]Northeast Climate Adaptation Science Center, USGS, [5]USDA Forest Service, [6]National Park Service

20. Using point counts to study how forestry management affects avian communities

Toni Lyn Morelli[1]

[1]USGS

Assessing Vermont Conservation Strategy: Safeguarding Biological Hotspots in High Priority Interior Forests

Meryl Callaway, University of Vermont

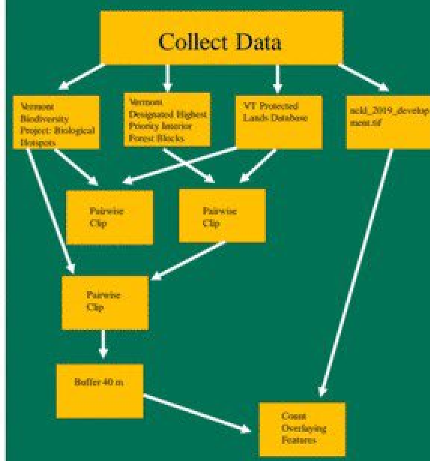
Intro

About Seventy six percent of Vermont's landscape is forested (Department of Forests, 2020). Increasingly, this percent of forest cover is shrinking due to anthropogenic need for increased development. These forests however house valuable ecosystems and ecological hotspots that should be important considerations for conservation efforts in Vermont. For this analysis, ecological hotspots are considered areas of high biological significance or diversity and are areas needed to preserve biological integrity.

Objectives:

1. Understand the effectiveness of current conservation efforts in Vermont in protecting high priority interior forests and the biological hotspots within them.
2. Determine the degree to which these conserved hotspots are protected from anthropogenic disturbance, defined as human impervious development.

Methods



Protected High Priority Interior Forests

Fig 1: Protected high priority interior forests in Vermont. Data from Vermont Geodatabase. Projection: Transverse Mercator. Coordinate System: NAD_1983_StatePlane_Vermont_FIPS_4400.

Biological Hotspots Protected within High Priority Interior Forests

Fig 2: Protected biological hotspots within the high priority interior forests of Vermont. Data from Vermont Geodatabase. Projection: Transverse Mercator. Coordinate System: NAD_1983_StatePlane_Vermont_FIPS_4400.

Results

- There were:

  - 1,033,660.4 hectares of high priority interior forests, 520,750.2 hectares of which were protected.

  - 265,156.4 hectares of biological hotspots, 227,253.6 hectares of which were protected within highest priority interior forests.

- All biological hotspots within high priority interior forests were conserved.
- All protected hotspots were within 40m of at least one area of developed land.

Conclusion

Biological hotspots are well conserved within the high priority interior forests of Vermont however not well protected from neighboring anthropogenic disturbance. It was found that all protected hotspots are within 40m of at least one source of impervious human development, possibly leading to the disturbance of organisms inside these protected hotspots.

This analysis provides valuable information for future conservation efforts in Vermont by discovering weaknesses in the current conservation strategies. Further research should analyze the degree to which organisms within the biological hotspots are impacted by neighboring disturbance. Additionally, no biological hotspots are conserved outside of the priority interior forests. Therefore, future research should work towards determining the most effective way of preserving these biological hotspots outside of interior forests.

Works Cited

"CadastralConserved_PROTECTEDLND". *VT Center for Geographic Information* 2021. Accessed 25 October 2023.

Capen, D.E. "EcologicHabitat_HOTSPOTS." *VCGI*, 2000. Accessed 25 October 2023.

Dewitz, J. "National Land Cover Database(*NLCD) 2019 Products* [Data set]." *U.S. Geological Survey*, 2021. Accessed 29 November 2023. https://doi.org/10.5066/P9KZCM54.

"Overview of Vermont's Forests." *Department of Forests - Parks and Recreation*, fpr.vermont.gov/forest/vermonts-forests. Accessed 29 Nov. 2023.

"Vermont Highest Priority Interior Forest Blocks." *ANR GIS*, 2016. Accessed 25 October 2023.

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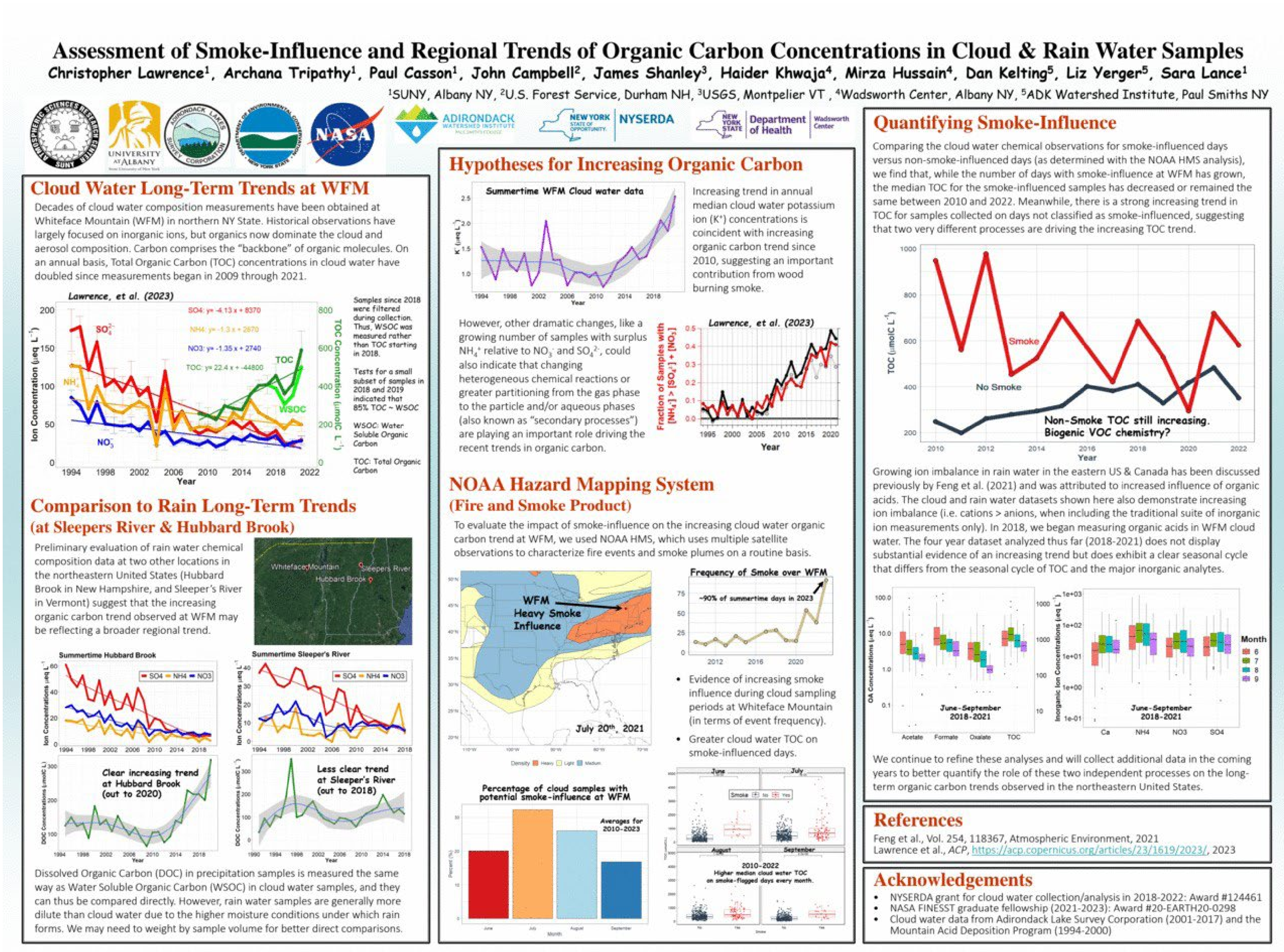

Assessment of Smoke-Influence and Regional Trends of Organic Carbon Concentrations in Cloud & Rain Water Samples
Christopher Lawrence[1], Archana Tripathy[1], Paul Casson[1], John Campbell[2], James Shanley[3], Haider Khwaja[4], Mirza Hussain[4], Dan Kelting[5], Liz Yerger[5], Sara Lance[1]
[1]SUNY, Albany NY, [2]U.S. Forest Service, Durham NH, [3]USGS, Montpelier VT , [4]Wadsworth Center, Albany NY, [5]ADK Watershed Institute, Paul Smiths NY
UNIVERSITY AT ALBANY
NASA
ADIRONDACK WATERSHED INSTITUTE
NEW YORK STATE OF OPPORTUNITY. NYSERDA
NEW YORK STATE Department of Health Wadsworth Center
Cloud Water Long-Term Trends at WFM
Decades of cloud water composition measurements have been obtained at Whiteface Mountain (WFM) in northern NY State. Historical observations have largely focused on inorganic ions, but organics now dominate the cloud and aerosol composition. Carbon comprises the "backbone" of organic molecules. On an annual basis, Total Organic Carbon (TOC) concentrations in cloud water have doubled since measurements began in 2009 through 2021.
Lawrence, et al. (2023)
SO4: y= -4.13 x + 8370
NH4: y= -1.3 x + 2870
NO3: y= -1.35 x + 2740
TOC: y= 22.4 x + -44800
TOC
WSOC
Ion Concentration (μeq L⁻¹)
TOC Concentration (μmolC L⁻¹)
Year
Samples since 2018 were filtered during collection. Thus, WSOC was measured rather than TOC starting in 2018.
Tests for a small subset of samples in 2018 and 2019 indicated that 85% TOC ~ WSOC
WSOC: Water Soluble Organic Carbon
TOC: Total Organic Carbon
Comparison to Rain Long-Term Trends (at Sleepers River & Hubbard Brook)
Preliminary evaluation of rain water chemical composition data at two other locations in the northeastern United States (Hubbard Brook in New Hampshire, and Sleeper's River in Vermont) suggest that the increasing organic carbon trend observed at WFM may be reflecting a broader regional trend.
Whiteface Mountain
Sleepers River
Hubbard Brook
Summertime Hubbard Brook
Summertime Sleeper's River
SO4 NH4 NO3
Clear increasing trend at Hubbard Brook (out to 2020)
Less clear trend at Sleeper's River (out to 2018)
Dissolved Organic Carbon (DOC) in precipitation samples is measured the same way as Water Soluble Organic Carbon (WSOC) in cloud water samples, and they can thus be compared directly. However, rain water samples are generally more dilute than cloud water due to the higher moisture conditions under which rain forms. We may need to weight by sample volume for better direct comparisons.
Hypotheses for Increasing Organic Carbon
Summertime WFM Cloud water data
Increasing trend in annual median cloud water potassium ion (K⁺) concentrations is coincident with increasing organic carbon trend since 2010, suggesting an important contribution from wood burning smoke.
However, other dramatic changes, like a growing number of samples with surplus NH₄⁺ relative to NO₃⁻ and SO₄²⁻, could also indicate that changing heterogeneous chemical reactions or greater partitioning from the gas phase to the particle and/or aqueous phases (also known as "secondary processes") are playing an important role driving the recent trends in organic carbon.
Lawrence, et al. (2023)
Fraction of Samples with [NH₄⁺] > [SO₄²⁻] + [NO₃⁻]
Year
NOAA Hazard Mapping System (Fire and Smoke Product)
To evaluate the impact of smoke-influence on the increasing cloud water organic carbon trend at WFM, we used NOAA HMS, which uses multiple satellite observations to characterize fire events and smoke plumes on a routine basis.
WFM Heavy Smoke Influence
July 20th, 2021
Frequency of Smoke over WFM
~90% of summertime days in 2023
• Evidence of increasing smoke influence during cloud sampling periods at Whiteface Mountain (in terms of event frequency).
• Greater cloud water TOC on smoke-influenced days.
Percentage of cloud samples with potential smoke-influence at WFM
Averages for 2010-2023
June July August September
2010-2022 Higher median cloud water TOC on smoke-flagged days every month.
Quantifying Smoke-Influence
Comparing the cloud water chemical observations for smoke-influenced days versus non-smoke-influenced days (as determined with the NOAA HMS analysis), we find that, while the number of days with smoke-influence at WFM has grown, the median TOC for the smoke-influenced samples has decreased or remained the same between 2010 and 2022. Meanwhile, there is a strong increasing trend in TOC for samples collected on days not classified as smoke-influenced, suggesting that two very different processes are driving the increasing TOC trend.
TOC (μmolC L⁻¹)
Smoke
No Smoke
Non-Smoke TOC still increasing. Biogenic VOC chemistry?
Year
Growing ion imbalance in rain water in the eastern US & Canada has been discussed previously by Feng et al. (2021) and was attributed to increased influence of organic acids. The cloud and rain water datasets shown here also demonstrate increasing ion imbalance (i.e. cations > anions, when including the traditional suite of inorganic ion measurements only). In 2018, we began measuring organic acids in WFM cloud water. The four year dataset analyzed thus far (2018-2021) does not display substantial evidence of an increasing trend but does exhibit a clear seasonal cycle that differs from the seasonal cycle of TOC and the major inorganic analytes.
OA Concentrations (μeq L⁻¹)
Inorganic Ion Concentrations (μeq L⁻¹)
June-September 2018-2021
Acetate Formate Oxalate TOC
Ca NH4 NO3 SO4
Month 6 7 8 9
We continue to refine these analyses and will collect additional data in the coming years to better quantify the role of these two independent processes on the long-term organic carbon trends observed in the northeastern United States.
References
Feng et al., Vol. 254, 118367, Atmospheric Environment, 2021
Lawrence et al., ACP, https://acp.copernicus.org/articles/23/1619/2023/, 2023
Acknowledgements
• NYSERDA grant for cloud water collection/analysis in 2018-2022: Award #124461
• NASA FINESST graduate fellowship (2021-2023): Award #20-EARTH20-0298
• Cloud water data from Adirondack Lake Survey Corporation (2001-2017) and the Mountain Acid Deposition Program (1994-2000)

Bringing genomics to the field: An integrative approach to seed sourcing for forest restoration

Anoob Prakash and Stephen Keller
Department of Plant Biology, University of Vermont, Burlington, VT-05405, USA

Introduction

Atmospheric warming has shifted the treelines towards high elevations and increased outbreaks of insect pests, while changes in precipitation have played a major role in increasing drought-induced mortality (Pachauri et al., 2014).

Environmental stressor's: Resulting in decline of abundance and extent of tree species due to the direct effects of higher temperature, drought stress and/or failure to meet chilling requirements (Kimmins & Lavender, 1987; McCreary et al., 1990).

Anthropogenic stressor's: Land use changes and deforestation have fragmented forests, reducing both the size and connectivity of remaining populations.

These problems are compounded in long-lived organisms like trees, which cannot keep pace with the changing climate through natural dispersal and whose long generation times make any loss of genetic diversity through mortality or demographic bottlenecks, a slow process to replenish.

Solution: Integrating population genomic approaches with restoration planning to inform seed sourcing decisions with an eye towards capturing a representative fraction of the regional diversity.

Materials and Methods

Study species: Red spruce (*Picea rubens* Sarg.) is a temperate coniferous tree species that has experienced widespread decline due to anthropogenic causes since the late 19th century and is a prime example of a tree species vulnerable to rapid changes in climate due to its isolated populations and limited within-population genetic diversity in the southern part of its range (Capblancq et al., 2020, 2021).

Seed selection: We focused on two measures of genomic variation to evaluate candidate sources – genetic diversity (GD) and genetic load (GL). These two measures were chosen based on our previous work in red spruce, in which they were found to be significant predictors of early-life fitness of seedlings (Capblancq et al., 2021) (Fig 1).

GD was estimated based on expected heterozygosity (H_{exp}) across all single nucleotide polymorphisms (SNPs), which provides a fundamental measure of genetic variation based on the frequency of heterozygous genotypes expected under Hardy-Weinberg equilibrium (Nei, 1973).

GL measures the accumulation of deleterious mutations in the population due to genetic drift. To obtain an estimate of GL in populations, we calculated the number of non-synonymous SNPs (Pn) and the number of synonymous (silent) SNPs (Ps), weighted by their corresponding frequencies (fn and fs, respectively).

We then estimated GL as the ratio Pnfn/Psfs under the well-supported assumption that the majority of nonsynonymous mutations are deleterious (Willi et al., 2018).

Following functional categories from SNPEff (Cingolani et al., 2012) was categorized as non-synonymous for GL calculation: *missense variant, splice acceptor variant, splice donor variant, splice region variant, start lost, stop gained, stop lost.*

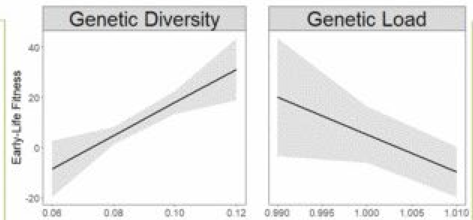


Figure 1. Marginal effects estimated from a multivariate linear model for Early-Life fitness for genetic diversity (GD) and genetic load (GL). Recreated from the results of (Capblancq et al., 2021) for the red spruce range edge.

Defining regional focus: Regional admixture provenancing strategy is based on sourcing seeds from a set of populations within the region of the target restoration sites that share a common biogeographic history and patterns of local adaptation (Bucharova et al., 2019).

Experimental design for monitoring restoration: Monitoring protocol at planting to enable tracking of establishment success (survival and growth through the second year). The monitoring design consisted of replicate georeferenced experimental plots stratified by seed source so that we could assess single-source variability at each site and compare the effect of single vs. pooled sources on trait variance (Fig. 2). Plot locations were buffered by 18m (16m plot radius + 2m buffer) in ArcGIS to avoid overlapping adjacent plots. Data on establishment success was collected 1 year after planting at the beginning of the growing season (April 2022).

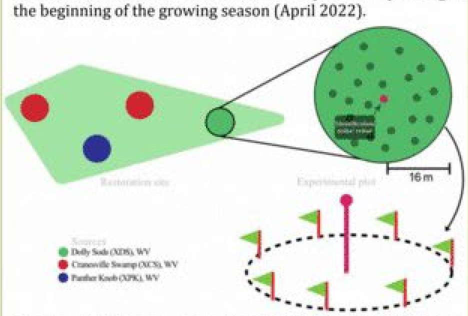


Figure 2. The experimental design for the red spruce monitoring effort. A circular experimental plot of radius 16m was established at the restoration site for reforestation monitoring and to assess the performance of individual sources. Each experimental plot consisted of forty plants from a single source to reflect the planting density of the reforestation activity. These single source experimental plots were marked with a central metal rod capped with a bright orange cap along with GPS coordinates for future monitoring efforts.

Coefficient of Evolvability (CV_G): To analyse the effect of single vs. pooled sources on evolutionary potential of trait variance in the restored populations. We used the seedling height data to calculate a scale-free measure of evolvability based on the genetic coefficient of variation (Houle, 1992)

$$CV_G = \sqrt{V_G}/\bar{x}$$

Where,
V_G is the genetic component of trait variance
$\bar{x}$ is the trait mean

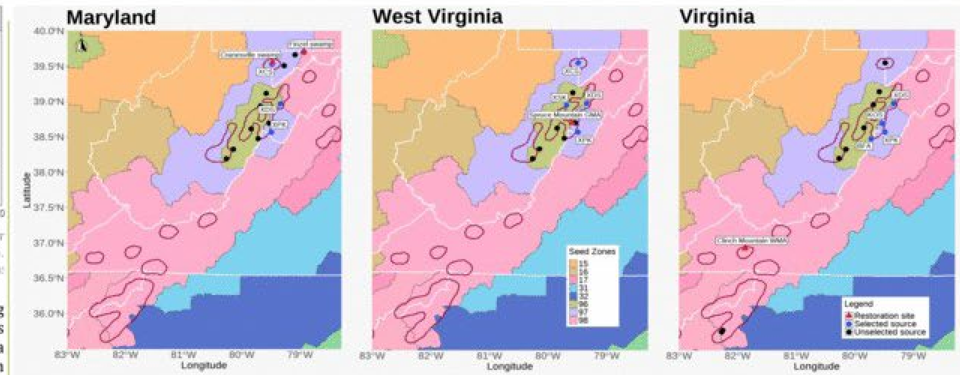


Figure 3. Study area and seed sourcing: The location of the red spruce restoration site and the seed sources selected for planting sites in Maryland, West Virginia and Virginia. The dark red polygons on the map are the known range extent of red spruce. The map colouring is based on the Eastern Seed Zone database.

Results

Regional admixture provenancing: The seeds sourced were mostly within the same climate-based seed zone or one seed zone away from the restoration site (Pike et al., 2020), keeping with the idea of environmental similarity during regional admixture provenancing (Fig 3).

Source pooling: Across the sites, CV_G and GD:GL were highest for the pooled sources compared to any single sources (Fig. 4). High CV_G for functional traits such as height can increase the resilience of populations to future environmental perturbations by increasing the genetic variability the population has for traits to respond to novel selection pressures.

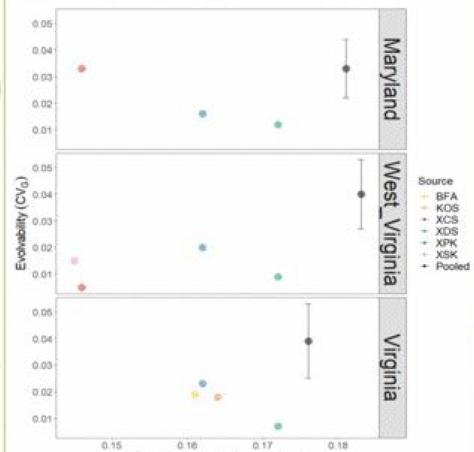


Figure 4. Evolvability (CV_G) for different sources planted at each restoration site and the bootstrapped pooled CV_G for source combinations at each site. The x-axis shows the GD:GL estimates for the singular and pooled sources.

Discussion

Major Findings

No "super sources" found across the sites, with the pooled combination for each site having high GD:GL and evolvability compared to any singular sources (Fig 4).

We found that GD:GL increased with set size until around four to five sources, beyond which there were minimal gains in diversity by combining additional sources (Fig. 5).

This work sets up the blueprint for successful collaboration between science and practice using a novel approach using forest genetics for ecological restoration. This science-practice-monitoring should be seen as a feedback loop rather than a one directional transfer of knowledge and skills. The work presented here is just a snapshot in time and it marks the beginning of conservation efforts that hopefully spans for centuries to come.

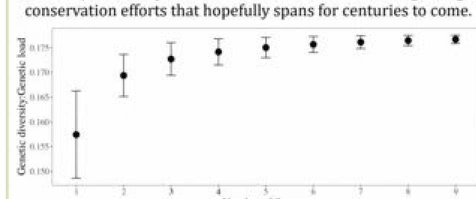


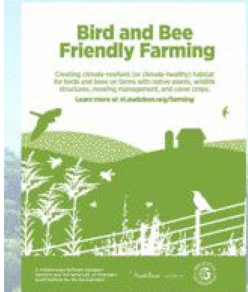
Figure 5. Total number of sources selected for restoration and their respective GD:GL estimate. The estimate for GD:GL flattens out around 4-5 sources with diminishing returns with increasing number of sources.

References

Developing a data-driven tool to advance bird and pollinator habitat evaluation and conservation in Vermont's working landscape

Cassandra Wolfanger and Margaret Fowle, Audubon Vermont

Audubon VERMONT · NRCS · WILD FARM ALLIANCE



Issue: Birds and pollinators are essential to agricultural crop production, pest control, and general ecosystem biodiversity, but have declined sharply range-wide in recent decades, including in Vermont and the surrounding region.

Solution: **Audubon Vermont's Bird and Bee Friendly Farming Program** to promote and implement practices on farms that provide essential foraging, breeding, and shelter resources that benefit birds and pollinators.

Proposed improvement: An **assessment tool that standardizes data collection, increases efficiency and consistency, and evaluates post-implementation success.** We'll use a 3-year Conservation Innovation Grant **(CIG)** from the Natural Resource Conservation Service to support the design, development, and piloting of a tool on Vermont farms.

What is the tool?

A science-based, app-driven software platform to enhance data collection and conservation practice recommendations to improve bird and pollinator habitat on farms.

Design Team & Partners

Audubon Vermont
National Audubon Society
Private GIS consultant
Natural Resources Conservation Service
Wild Farm Alliance

Reference Platforms

- ArcGIS Field Maps; other Arc GIS apps
- Wild Farm Alliance Bird Habitat Tool
- Audubon Conservation Ranching
- Audubon Bird Friendliness Index
- Cool Farm Alliance Biodiversity Tool
- Xerces Society Forms

User Audience

Conservation Professionals (in-field) → Farm Managers (end report)

Key Features

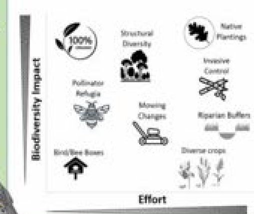
- Geo-referencing capabilities
- Northeast region specific native plant, bird, and pollinator species
- Built-in decision tree for applicable farm operations and management
- Scoring system for current conditions
- Ranking and matching system for recommending best fit NRCS practices
- Easy-to-understand outputs
- Ability to measure change over time, including pre- and post- interventions

Examples of Data Inputs

- Landscape features– using land cover type within 2 mile radius
- Habitat types and land use on-site
- % invasive plant cover
- % native vegetation/natural area cover
- Diversity of native plant composition
- Structural complexity of edge habitats
- Cover crop diversity
- Hay and pasture management strategies
- Bird and bee abundance and diversity data on-site and surrounding area
- Food, shelter, breeding resource availability

Scoring and Ranking

Prioritize based on:
- Ecological value of an action
- Economic feasibility
- Farm conditions and management



Examples of Conservation Practices Potentially Recommended

Target Areas

- Addison and Chittenden counties
- 6,800 farms statewide in Vermont, making up approximately 1,200,000 acres (UDSA, 2023).
- Estimate 3-5 farms to pilot tool in 2024
- Expand to network of over 30 farms to date

Expected Outcomes

- **Improved communication** with farmers and more effectively conveyed recommendations
- **Increased engagement, understanding of importance of conservation**
- **Increased acres managed for birds and bees; reversed population declines**
- **Demonstration of accomplishments and tracking changes over time**
- **Multi-metric biological inputs supplement traditional assessment strategies (abiotic resources—water quality, soil health, nutrient pollution) for a more comprehensive, descriptive on-farm decision-making process that integrates biological diversity into ecosystem services.**

End Product Written Report

Mapped site observations
Best match action recommendations
Farm operation & biodiversity scores

Credits
Bird and Bee Friendly Farming program content: Margaret Fowle/Audubon Vermont
Photography: Gwendolyn Causey, Cassie Wolfanger, Caroline Samson/Audubon Photography Awards, American Meadows, Monica Jorge/Audubon CT
Illustrations: University of Maryland Center for Environmental Science Integration and Application Network at ian.umces.edu/media-library. Artists: Tracey Saxby, Dylan Taillie, Dieter Tracey, Kim Kraeer, Lucy Van Essen, Emily Nastase, Sally Bell, Annie Carew, Jane Thomas, Jane Hawkey, Lucy Van Essen-Fishman.

Establishment of a new white oak common garden on the Green Mountain National Forest

John R. Butnor[1], Paula F. Murakami[1], Laura E. DeWald[2], C. Dana Nelson[3], Chris A. Maier[4]

[1]USDA Forest Service, Northern Research Station, Burlington, VT
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[3]USDA Forest Service, Southern Research Station, Lexington, KY
[4]USDA Forest Service, Southern Research Station, Research Triangle Park, NC

BACKGROUND

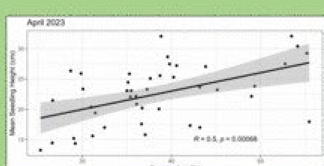
White oak (*Quercus alba*) occurs throughout eastern U.S. forests where it is an important component of forest biodiversity. It is highly valued by wildlife as well as the forest products industry. There is concern related to: regeneration of oak seedlings and saplings in existing stands, re-establishment of oak within stands that have been harvested, and future availability of desirable quality oak. Environmental threats, including invasives and pests, as well as a warming climate, challenge the long-term sustainability of this vital forest tree species and its habitat.

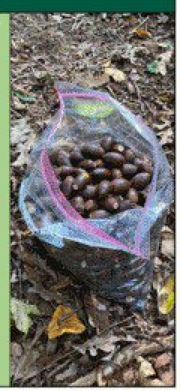
We established a white oak common garden on the Green Mountain National Forest (GMNF) in East Dorset, Vermont in April 2023, as part of a collaboration with the White Oak Genetics and Tree Improvement Project at the University of Kentucky. The aim of the project is to evaluate climate adaptative traits, assess suitability on a wide range of sites, identify superior performance, and inform restoration and assisted migration strategies for the species. We planted seedlings from 44 half-sib families in 20 replicates and assessed their growth and foliar phenology during the 2023 growing season. The families are broadly grouped geographically with an eastern transect from North Carolina to Vermont and a mid-western transect from Ohio to Minnesota.

The white oak common garden was planted on the GMNF in East Dorset, VT on April 19-20, 2023. Purple circles on the map above represent origins of 44 half-sib families that comprise the common garden in East Dorset, VT.

GERMINATION RESULTS

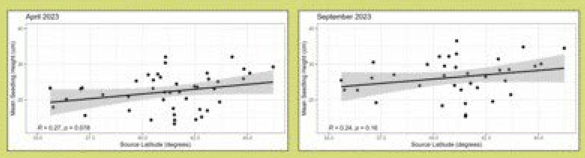
Mean seedling height of individual families at the time of planting in Vermont (April 2023), was positively related to germination success at the Kentucky State Nursery (P=0.0007). Many factors can impact acorn quality and germination, such as adequate pollen from nearby trees, local gene diversity, and environmental conditions at the time of flowering. We observed that families with higher germination rates were taller, and those with lower germination were shorter.



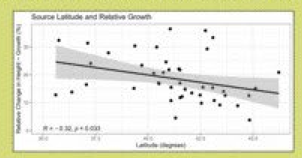


SURVIVAL AND GROWTH RESULTS

Seedling survival was excellent and ranged from 88 to 100 % depending on family, with no obvious latitudinal trends. Mean seedling height at the time of planting and at the end of the growing season (September 2023) was compared with source latitude to discern whether growth was influenced by north-south origins of individual families. While regression analyses indicated no significant associations at either timepoint, seedlings from more northerly latitudes tended to be taller at the time of planting (P=0.078) with the trend flattening by the end of the growing season (P=0.160).

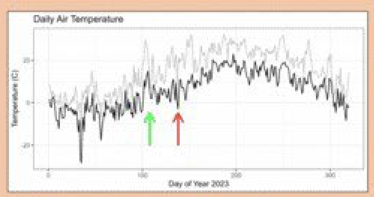


When relative change in seedling height from April to September was considered, a significant relationship emerged where families with southern origins tended to grow more than their northern counterparts in Vermont (P=0.033).



SPRING PHENOLOGY RESULTS

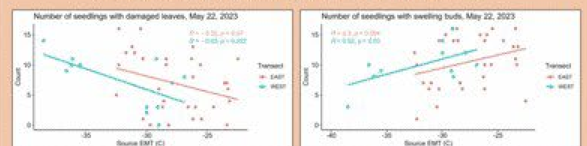
A freeze event on May 18, 2023, caused widespread damage throughout northern New England and New York. During this event, minimum air temperature reached a low of -3 °C in East Dorset, VT. In response, we conducted spring bud phenology assessments and quantified foliar frost damage on May 22, 2023.



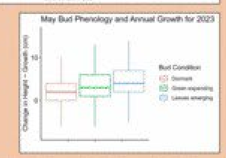
Seedlings were planted in East Dorset, VT on April 19-20, 2023 (green arrow). The grey line represents daily maximum temperature while the black line represents daily minimum temperature (www.visualcrossing.com). The red arrow represents a region-wide frost event that occurred on May 18, 2023.

On May 22, we discovered that ***all seedlings*** with newly emerged leaves were damaged by the frost event. When the number of seedlings with foliar frost damage in each family was compared to the extreme minimum temperature (EMT) of their origin (ClimateNA), there was a significant relationship among seedlings in the West transect (P=0.022) and similar trend with the East transect. Families whose leaves emerged early were most susceptible to foliar frost damage. Seedings with swollen buds were not damaged.

More seedlings from colder regions suffered freeze damage



Despite suffering significant foliar damage early in the growing season, these "early-emerging" individuals had superior height growth (see box plot to right).

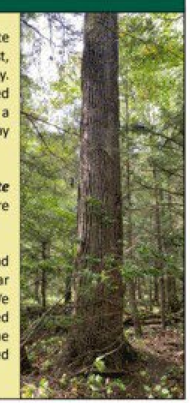


CONCLUSION AND FUTURE PLAN

We are pleased with the successful establishment of this white oak common garden on the Green Mountain National Forest, despite experiencing significant freeze damage in mid-May. Families that experienced the most freeze damage exhibited greater growth by the end of the growing season. Instead of a single terminal bud, white oak have a cluster of buds which may offer ready "replacements" for isolated freeze events.

While these are very early results, there is ***evidence of climate adaptation*** in growth and phenology, which could inform future acorn collection and planting strategies.

In the years to come, we will assess survival, growth, and response to climate via assessments of spring bud and foliar phenology, leaf physiology, as well as winter cold tolerance. We plan to incorporate additional families from regionally sourced acorns (VT, NH, MA and NY). These families were planted at the New York State tree nursery in autumn 2023 and will be added to the white oak common garden in spring 2025.



ACKNOWLEDGEMENTS

We would like to acknowledge the many volunteers who collected the acorns that made this installation possible. The staff of the Green Mountain National Forest was instrumental in providing a planting location, site preparation, infrastructure support and ongoing maintenance especially Jeff Tilley, Josh Wills, Stacey Stratton and James Donahey. Peter Anderson, Steven Flurry, Bert Abbott and Pat Abbott all traveled to Vermont to help plant in April 2023.

Genomic offset modeling for climate-smart seed conservation in red spruce

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[3] University of Vermont, Rubenstein School of Environment and Natural Resources
[3] University of Maryland, Center for Environmental Science

Acknowledgements: We appreciate the assistance of Nick LaBonte, Jeff Tilley, James Donahey, Susanne Lachmuth, and Brit Verrico. Funding was provided by the US Forest Service Forest Health Protection (FHP) program, agreement 23-CS-11242307-098.

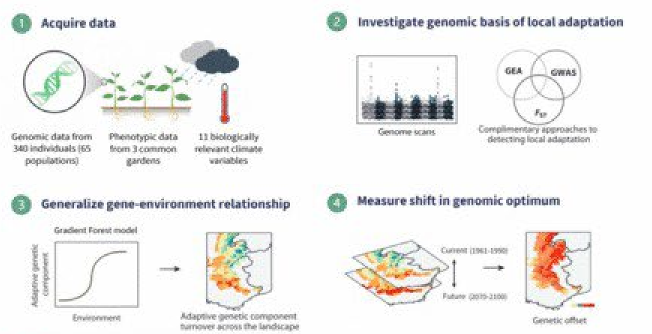
Highlights

- Climate change is disrupting local adaptation and shifting gene-environment relationships.
- When choosing seed for restoration projects, local is not always best. We should select seed likely to be adapted to the target location's future climate.
- We used genomic offset modeling to select red spruce seed sources for a climate-smart seed orchard in the Green Mountain National Forest.
- There is a tradeoff between adaptation to future climates throughout New England and ability to survive current conditions at the orchard site.

Abstract

Red spruce (*Picea rubens*) is highly vulnerable to climate change and has been a target of significant conservation efforts, including assisted migration. Although restoration has historically followed a "local is best" paradigm, climate change is disrupting local adaptation and shifting prior gene-environment relationships. Our team has mapped climate-adaptive diversity across the range of red spruce, integrating population genomics with spatial models to identify stands most likely to experience a disruption in climate adaptation. This allows us to predict which trees should be moved where to maximize fitness under future climates. Here, we combine genomic and climate data to model genomic offsets, a measure of climate maladaptation, in order to select 15-20 red spruce stands from which to collect scions and graft them onto root stock for future out-planting into a seed orchard site in the Green Mountain National Forest. We will identify 50-100 total genotypes, adapted to a range of future climate conditions anticipated in the northeast by the end of the century. Our objective is to conserve climate-adaptive genetic diversity in red spruce and produce at-scale quantities of seed for restoration plantings under future climate change.

Genomic Offset Modeling



5 Validate predictions

Fig. 1. Adapted with permission from Capblancq, *et al.* 2020. Genomic Prediction of (Mal)Adaptation Across Current and Future Climatic Landscapes. *Annu. Rev. Ecol. Evol. Syst.*

Donors: 4,712 current red spruce localities in greater New England are candidates for the seed orchard.

Recipients: 27,216 gridded cells across greater New England represent possible locations of future restoration plantings under climate conditions for the years 2070-2100.

We want to choose genotypes that have minimal genomic offset with as many potential future sites as possible. However, these trees must also be able to survive current conditions at the seed orchard. The seed orchard will also serve as a means of validating the genomic offset model predictions.

Background

Red spruce is a conifer found at high elevations in the Appalachian Mountains and northern maritime forests, where it is valued for its timber, wildlife habitat, and ecosystem services. It is most abundant in New England, Nova Scotia, and eastern Quebec, but the range extends as far south as North Carolina, where populations can be found on "sky islands"—isolated patches of suitable habitat left behind on mountaintops in the wake of receding glaciers (Fig. 2). Red spruce is adapted to cool, moist climates with low potential evapotranspiration. The USDA's Climate Change Tree Atlas predicts poor capability for red spruce to persist under future climate change, as well as a substantial reduction in suitable habitat. Hundreds of thousands of seedlings are used in red spruce restoration each year, yet the seed required to meet this demand currently comes from single-tree collections with limited provenance diversity. There is an urgent need to (1) conserve existing genetic resources to maximize the ex-situ banking of adaptive diversity, and (2) increase capacity for seed production for large-scale restoration and assisted migration plantings. This project will establish a seed orchard that will produce large quantities of genetically diverse seed exhibiting climate adaptation broadly applicable to reforestation and assisted migration plantings throughout the region.

Fig. 2. Map of red spruce current distribution (green) and extent of study (red outline). Site of future seed orchard in the Green Mountain National Forest in Bristol, VT is marked with a pin.

Candidates with low landscape-wide genomic offset in the future are least likely to do well in the Bristol site's current climate.

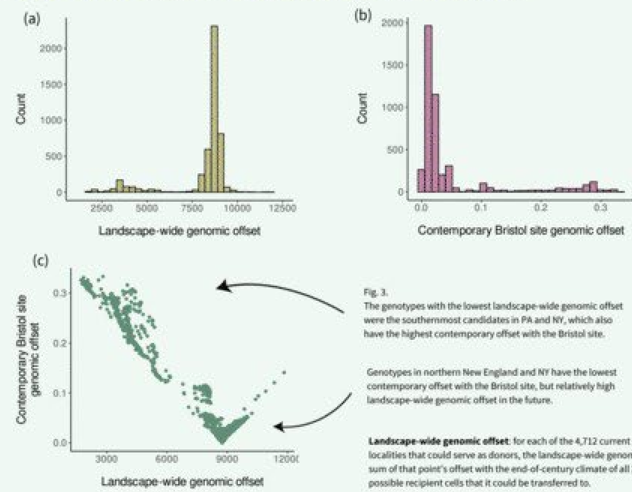


Fig. 3.
The genotypes with the lowest landscape-wide genomic offset were the southernmost candidates in PA and NY, which also have the highest contemporary offset with the Bristol site.

Genotypes in northern New England and NY have the lowest contemporary offset with the Bristol site, but relatively high landscape-wide genomic offset in the future.

Landscape-wide genomic offset: for each of the 4,712 current red spruce localities that could serve as donors, the landscape-wide genomic offset is the sum of that point's offset with the end-of-century climate of all 27,216 possible recipient cells that it could be transferred to.

Summing only the offsets of the best 0.5% recipient sites reduces the tradeoff.

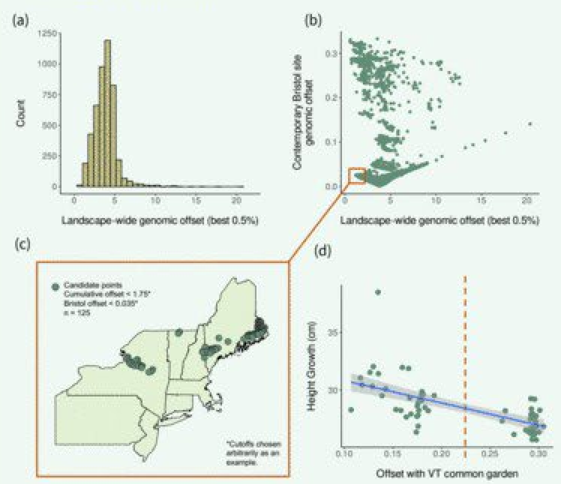


Fig. 4. (a) Distribution of landscape-wide genomic offsets for each of the 4,712 candidate donors, summing only their future offsets with the 0.5% of possible recipient locations with which they have the lowest offset (i.e., the best match for future transplantation). (b) All candidate donors plotted by landscape-wide genomic offset (best 0.5% match) and contemporary offset with Bristol orchard site. (c) Map of example set of candidate points chosen from distribution in (b). (d) Genomic offsets of genotypes transplanted into VT common garden and their height growth as a proxy for seedling fitness (dead seedlings scored as zero). Higher offset correlates to lower fitness. Red line indicates proposed threshold for survival at Bristol site.

However, the best recipient sites for these top candidate donors are highly geographically clustered.

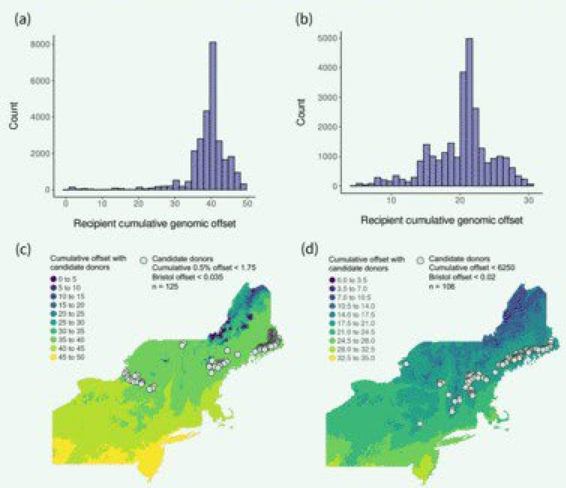


Fig. 5. (a) For each potential recipient locality, sum of its offset with the 125 candidate donors shown in Fig. 4c. Most recipient locations have high offset for these donors. (b) Recipient cumulative offsets for an alternative set of 106 donors selected based on low landscape-wide genomic offset (not restricted to best 0.5% matches). (c) All possible recipient locations colored by offset with candidate donors from Fig. 4c. Locations with low offset relegated to only a small area in northern Maine. (d) All possible recipient locations colored by offset with candidate donors from Fig. 5b. Geographic spread of acceptable recipient locations is far higher than in Fig. 5c.

Next steps

- Incorporate Forest Inventory Assessment data on spruce presence / absence, as well as logistical considerations such as distance from roads and public vs. private land.
- Investigate sensitivity of predictions to different climate model scenarios and time points (e.g., 2040-2070).
- Examine climate space and geographic space covered by different candidate donor sets. Formalize selection criteria. Scions will be collected in early spring 2024.

To test how different parameter choices affect set of donor points, please visit the dashboard at **bit.ly/spruce-dashboard**

Email: nora.heaphy@uvm.edu

SCAN ME

Climate Change Exposure Mapping

Lukas Kopacki, Jen Pontius, Tony D'Amato, James Duncan

Important work has been done downscaling projected changes in climate conditions, modeling shifts in suitable habitat, and mapping historical disturbance patterns across the region to better inform forest management under changing climate regimes. But none has combined all these products into one cohesive assessment of potential forest exposure to climate change, how it varies by species and across the region.

The Northeastern Forest Climate Change Exposure Mapping Tool was designed to aggregate these valuable but disparate spatial data sets to provide a more comprehensive assessment of relative exposure to climate change at the species and community levels.

Methods

Input Data Layers – normalized based on data distribution across the region

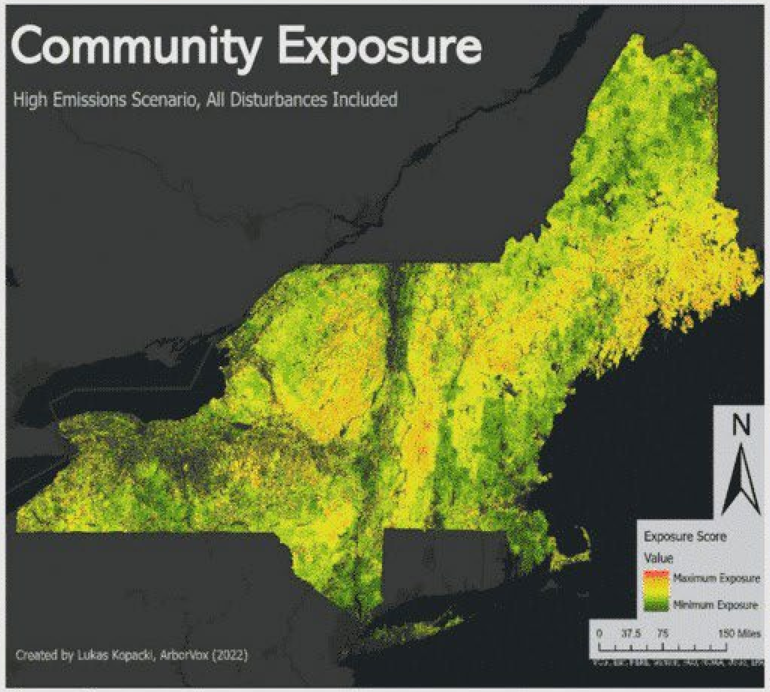
- Species Abundance – FEMC Species Basal Area Maps
- Disturbance Frequency – FEMC Forest Health Atlas
- Projected Change in Suitable Habitat – Climate Change Tree Atlas
- Predicted change in climate metrics – Developed as a part of this project based on TerraClimate data

Species- Specific Exposure Calculations

For each species, the sum of the normalized input data layers was used to calculate an aggregate climate exposure value at the 30m pixel level. Aggregate models were created for low and high emission scenarios and three disturbance scenarios (no disturbance, all disturbance, climate related disturbance only).

Community Exposure Calculations

Community-level climate exposure models were developed to aggregate exposure across all species present at each 30m pixel. Calculated as a weighted (%BA) average of species-level climate exposure values, the result is map of relative climate exposure for forested systems that can be used to help inform adaptive management across the region.



Results

At the stand level, highest overall exposure to changing climate conditions, disturbance frequency, and shifts in suitable habitat is concentrated in mountainous regions throughout the region and southeastern Maine.

Relative exposure across all species increases by 4 percent between low and high emission scenarios, although the differences between individual species varies widely.

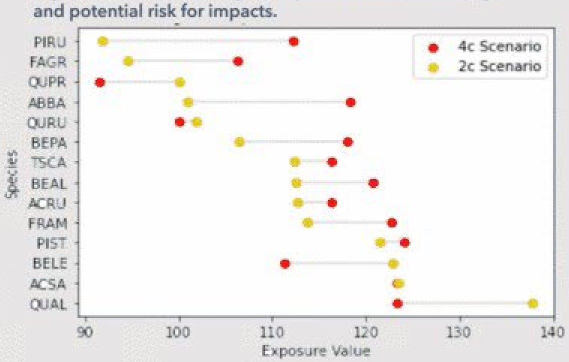
Web Tool

The FEMC hosts an ArcGIS Online-leveraged GIS hub with raster-based tile maps for each input data layer, each species and community level exposure maps for multiple climate and disturbance scenarios. Maps can be viewed via the online GIS hub or downloaded directly from the FEMC website

Much of our current management is guided by the outcomes of decades of silviculture research, yet many of the conditions under which those results were generated are rapidly changing. These relative exposure maps can help to inform where climate adaptation management applications may be most necessary and successful over time.

Climate Exposure by Species:

For all map products higher values indicate higher exposure to climate change and potential risk for impacts.



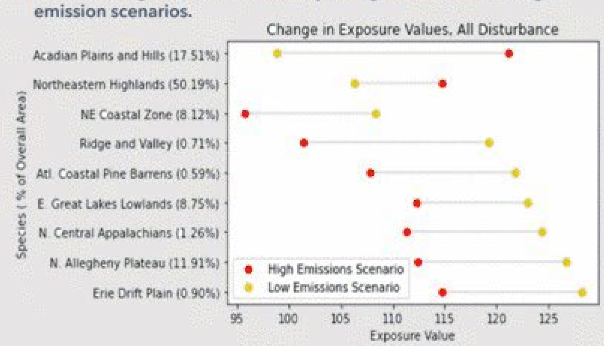
Species Included in Analysis

Northern red oak	Yellow Birch	Red Maple
White oak	Eastern white pine	American Beech
Chestnut Oak	Red spruce	White Ash
Black Birch	Balsam Fir	Eastern Hemlock
Paper Birch	Sugar Maple	

FEMC

Climate Exposure by Ecoregion:

Comparisons by Ecoregion highlight the variability of climate exposure that can be expected across the region and how that may change under low and high emission scenarios.



Northeastern Forest Inventory Network

Overview

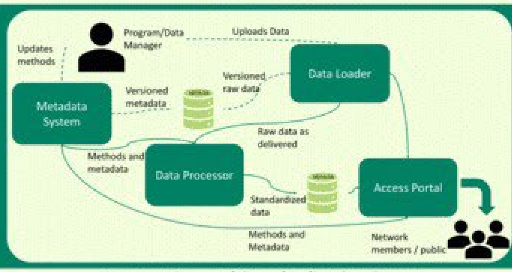
There are numerous continuous forest inventories (CFI) that have recorded forest conditions across the northeastern United States for the past several decades. The Northeastern Forest Inventory (NEFIN) project was developed as a collaborative effort led by the FEMC to aggregate and standardize CFI data from monitoring programs across the region into a single online tool. The goals of this project were to; (1) increase the accessibility and usability of forest inventory data from disparate collections in the northeastern US; (2) allow use of these data to investigate trends in and drivers of forest growth and yield over time; and (3) enable greater exchange of information and expand collaborations around analyzing trends in northeastern forests.

This poster provides an overview of the NEFIN tool that standardizes data from several CFIs and provides ways to search, aggregate and download that data.

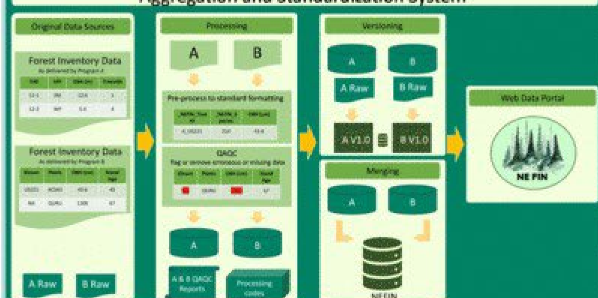
Objectives

- Provide standardized CFI data from disparate datasets both current and historical
- Create a system that can standardize unique datasets with the flexibility to handle temporal changes in data structure and sampling methods.
- Make the system for upload and download as easy as possible to make continued use as likely as possible.
- Build a network of experts that are better able to collaborate regarding CFI management and methods.

Architecture



Aggregation and Standardization System



Metadata Analysis

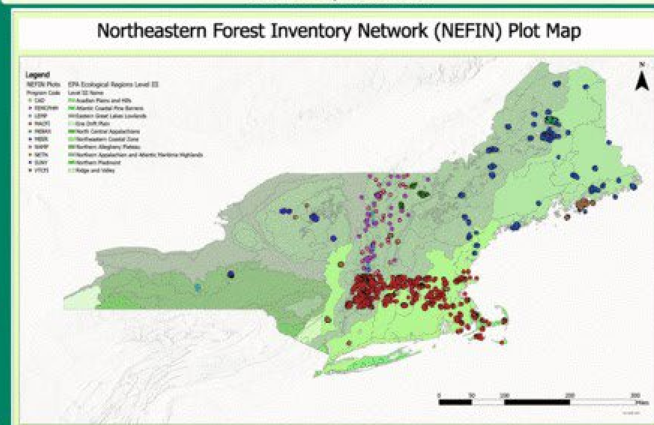
Forest inventory methods can range widely from program to program, and even similar standard practices can yield structurally disparate datasets. A metadata analysis was conducted for 8 forest inventory programs across the Northeast. From this metadata analysis a subset that met the required measurements for the NEFIN system. The metadata analysis was conducted to make sure that the normalization and standardization of key individual metrics and overall methodology would support analysis using the subsequently unified database.

Comparison tool:
https://www.uvm.edu/femc/forest_inventory_data_network/methods/comparison

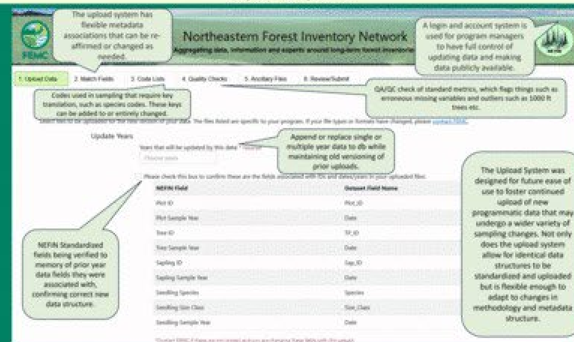
Raw Data Storage

Raw data is both versioned and stored upon upload as a CSV to be available for download and is stored in JSON format within the standardized table. The raw data are stored as a single JSON object in a 'doc' type field in the MySQL Database. This provides added utility, including direct visualization of the data on the front end, and filtered selection of individual rows with unique criteria such as the presence or absence of forest health related sampling.

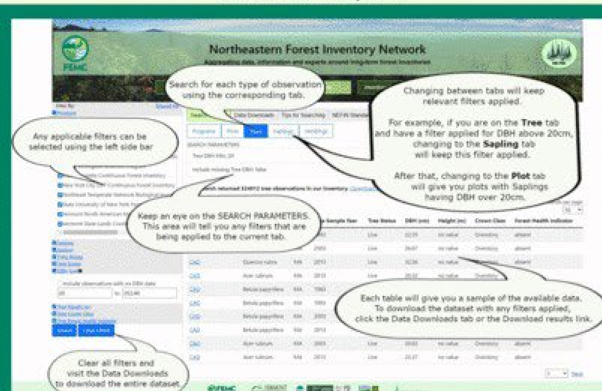
Database Spatial Extent



Upload System



Data Download System

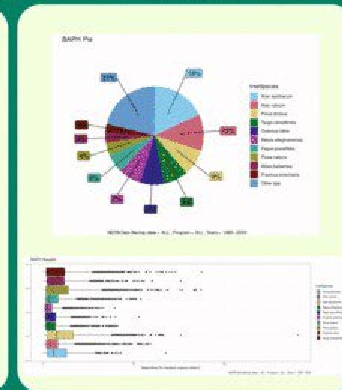


Data Processing and Visualization

As an added benefit to both program managers and public users, summary data visualization is provided using server-side processing and user interactive visualization using an R-Shiny application. The application allows users to visually examine the publicly available data using several useful plots and summary options. These allow for summary statistics that allow for quick insights into the NEFIN database.

Filter Selection

Data Visualization



Summary

More than just a unified and standardized dataset that provides spatially explicit and temporally varied data, NEFIN has built the web and database architecture to handle complex data sampling over longer periods of time. Not only does the system standardize disparate data in a way that can be used in regional analysis, but it also gives CFI program managers the flexibility to adapt the data's structure in a semi-automated way. The upload system can handle common changes that occur in plot monitoring so that a program can continue to integrate their monitoring network efforts into the larger NEFIN network that may be better able to answer regional forest and broader ecological questions.

Why Are These Data Useful?

- Forest management: Informing decisions on sustainable use and long-term planning.
- Timber production: Estimating volumes and predicting future yields.
- Biodiversity conservation: Identifying conservation areas and tracking species presence.
- Carbon sequestration and climate change mitigation: Assessing carbon stocks and impacts on climate change.
- Research and monitoring: Supporting scientific studies and ecological understanding.
- Forest health monitoring: Detecting pests, diseases, and invasive species.
- Ecosystem services assessment: Evaluating water purification, soil erosion control, and habitat provision.
- Forest fire risk assessment: Assessing fire risk and aiding fire management strategies.
- Machine learning and AI applications: Enhancing data analysis, predictive modeling, and decision-making.
- Geospatial modeling: Provides spatially fixed and temporally varied training and testing sites

Challenges and Future Questions

- Edge case management resulting from data unification and standardization.
- Build out a data program template so that smaller programs can be easily incorporated into the system.
- Additional standardized fields such as explicit forest health parameters.
- Provide standardized protocol and manuals that standardize metric sampling to make unification easier.

Acknowledgements & Authors

James Duncan•, Emma Tait •, Nancy Voorhis, Alexana Wolf, Soren Donisvitch, Jennifer Pontius, Clark Cooper •

• Prior Employees no longer affiliated with FEMC

Explore NEFIN

https://www.uvm.edu/femc/nefin/

Recreational Impact on Facets of Forest Health

Overview

Recreational activities, particularly hiking and biking, have experienced a notable surge in popularity, a trend exacerbated by the onset of the COVID-19 pandemic. This increased engagement presents a unique opportunity for individuals to establish meaningful connections with forested landscapes. While the uptick in recreational usage is positive for human well-being and nature appreciation, it concurrently raises concerns about potential impacts on forest health, specifically pertaining to soil quality, wildlife habitats, and the broader ecological equilibrium within forest ecosystems.

Numerous studies have underscored the positive impacts of outdoor recreation on human well-being and mental health, emphasizing the importance of nature experiences in mitigating stress and promoting physical activity (Bowen et al., 2018; Bratman et al., 2019). However, the dynamic interplay between heightened recreational activities and potential consequences for forest health necessitates a comprehensive understanding of the ecological implications.

The Forest Ecosystem Monitoring Cooperative (FEMC) embarked on a project spanning 2022 and 2023, specifically designed to delve into the multifaceted interactions between recreation, soil vulnerability, wildlife disturbance, and overall forest health. By employing advanced geospatial analysis techniques, the project aimed to elucidate how recreational activities impact soil quality and wildlife habitats. Moreover, the study sought to create actionable products that could aid in the effective management of recreation in forest ecosystems.

The findings of this research endeavor are expected to contribute valuable insights for land managers, conservationists, and policymakers, facilitating a balanced approach that considers both the benefits of recreation and the conservation of vital ecological components. By exploring the nuanced relationships between human activities and forest health, the project aims to inform sustainable management practices, ensuring that recreational engagement with forested landscapes can coexist harmoniously with the preservation of ecological integrity.

This project aimed to investigate the impact of recreational hiking and biking on forest health. The analysis utilized several geospatial data sources, including ForWarn sentinel data, STRAVA recreational use data, NLCD forest data, and USDA soil survey data. The primary objectives were to determine whether recreational activities affect canopy health and if so, whether those effects can be detected with ForWarn; identify areas where soils are more susceptible to recreational use; and assess the disturbance of wildlife in forested landscapes used for recreational activities.

Methods

1. ForWarn Sentinel data: We integrated ForWarn sentinel data to monitor forest health indicators, such as vegetation stress and disturbance events, and examined whether these metrics could be linked to recreational activities.
2. NLCD Forest and USDA Soil Survey data: We combined NLCD forest data and USDA soil survey data to create geospatial datasets that allowed us to identify areas with soils susceptible to recreation and to assess how these soils were being used on the landscape.
3. Wildlife disturbance analysis: Our research also explored the potential impact of recreation on wildlife. We mapped areas where wildlife was likely to be disturbed by outdoor activities, and determined both how often that disturbance occurs and the average size of undisturbed forested parcels.
4. STRAVA recreational use data: We leveraged STRAVA's recreational use data, which shows usage density on all trails across the project region, to assess the spatial distribution and intensity of hiking and biking activities—this added an additional dimension to our above analyses.

Strava Forwarn Findings

Canopy Health and Recreational Use:

- Significant but weak positive correlation between forest canopy health and recreational use.
- Areas with hiking and biking recreation tend to exhibit a greener and healthier forest canopy.
- Two-sample t-test shows a statistically significant difference, reinforcing the positive relationship.

Remote Sensing with ForWarn:

- ForWarn NDVI deviance from norm during the growing season used for remote sensing.
- Statistically significant relationship found between areas with recreational activities and generalized changes in forest canopy health.
- Correlation indicates a positive association, but causative link not established.

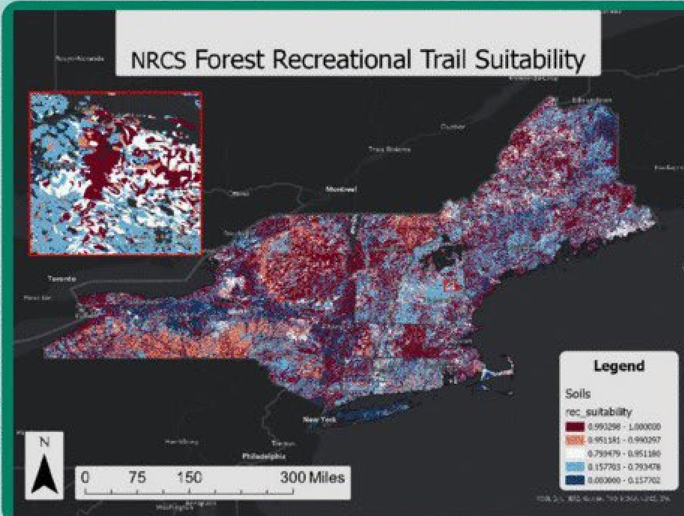
Positive Relationship Implications:

- Positive correlation implies that recreation-prone areas have a greener and healthier forest canopy during the growing season.
- Statistical significance reinforces the observation of improved forest health in recreation-prone areas.
- Cautious interpretation required, acknowledging the complexity of forest ecosystems and the multifactorial nature of observed changes.

Recreation and NDVI Relationship:

- Linear model reveals nuanced associations between Strava hiking/biking and NDVI deviance.
- Intercept (8.369e+00) denotes baseline mean NDVI deviance.
- Hiking shows a slight, statistically significant decrease (p-value: 0.008668), while biking exhibits a slight increase with significance (p-value: 0.000486).
- Limited explanatory power (Multiple R-squared: 8.939e-05, Adjusted R-squared: 7.79e-05) emphasizes the complexity of recreational impacts on **forest health.**

State Specific Hiking and Biking Use Findings



State Specific Hiking and Biking Outliers

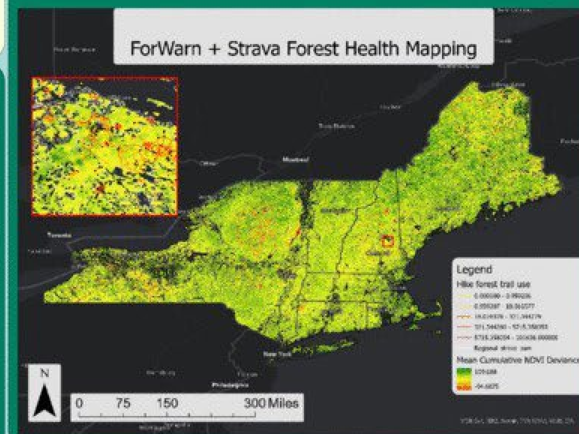
Hike and Bike per Square Kilometer:

- Rhode Island (RI):
- High values may suggest that the state's compact size attracts both residents and tourists for recreational activities.
- New Hampshire (NH):
- The state's scenic landscapes and outdoor attractions likely contribute to higher engagement in recreational activities, appealing to both residents and tourists.

Average Hike and Bike per Capita:

- Vermont (VT):
- High per capita values may indicate a strong outdoor culture, attracting both residents and tourists seeking recreational experiences.
- New Hampshire (NH):
- Similar to the per square kilometer analysis, NH stands out, suggesting a high level of recreational engagement among residents and potential tourists.

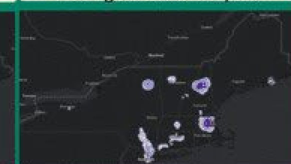
ForWarn Composite Mean NDVI Deviance Health Proxy

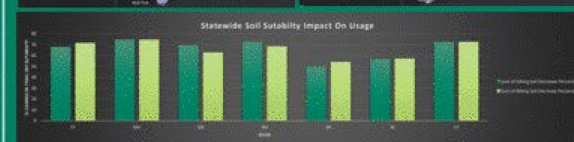


Soil Use Hotspot Analysis

Biking Soil Use Hotspots

Hiking Soil Use Hotspots





Soil Susceptibility:

- Geospatial data identifies certain forest soils as more susceptible to degradation due to recreation.
  - Biking – Vermont and Massachusetts where the states with the most use on the lest suitable soils
  - Hiking – Massachusetts and New Hampshire were the states with the most hiking use on the least suitable soil s
- Enables targeted conservation efforts to address soil vulnerability and promote sustainable land management to mitigate soil impacts which may have direct effects on tree and vegetative health.

Wildlife Disturbance (nor enough room to display):

- Recreational activities lead to a significant reduction in the size of undisturbed parcels of forested land.
- Implications for biodiversity as wildlife habitats are impacted by human recreation.
- Geospatial products aid in prioritizing areas for wildlife conservation efforts.

Summary

In conclusion, this project provided valuable insights into potential impacts of recreation on forest health, using a multi-faceted approach that combined remote sensing data, geospatial analysis, and wildlife disturbance assessments. The products created during the course of this project can inform decision-making and management strategies to ensure the preservation and sustainable use of forested landscapes, particularly by assisting land managers in identifying areas that are a priority for different management objectives. While the analysis utilized available data sources and remote sensing techniques, the lack of comprehensive field-based data presented a substantial limitation. Recognizing the importance of such data and addressing the challenges in collecting and standardizing it is essential for future research aiming to assess the impacts of recreational activities on soil, wildlife, and forest health more accurately.

Acknowledgements & Authors

Authors: Soren Donisvitch, Alison Adams, Matthias Sirch, Elissa Schuett, Larissa Robinov, Jerome Lee, Jennifer Pontius

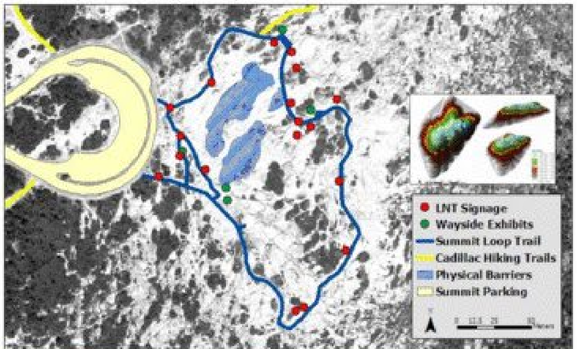
State Strava Data Coordination: Aaron Bergdahl, Jessica A Cancelliere, Savannah Ferreira, Jeff Harriman, Jeff Ward, Joshua Halman, Nicole Keleher, Eric Peterson, Alana Russell, Elisabeth Ward, Jeffrey Ward, Larissa Robinov
Expert Committee:
Johanna Lyons, Min Kook Kim, Claire Polfus, Eric Peterson, Danielle J Johnson, Daniel Evans, Matthew Gallo, John Schmid

Remote Sensing Technologies and the Monitoring and Management of Subalpine Summits, Acadia National Park

Min Kook Kim, Associate Professor, Dept. of Natural Resources and the Environment, Marshall University (mkkim2@gmail.com)
John Daigle, Professor, School of Forest Resources, University of Maine (jdaigle@maine.edu)

Background: Cadillac Mountain

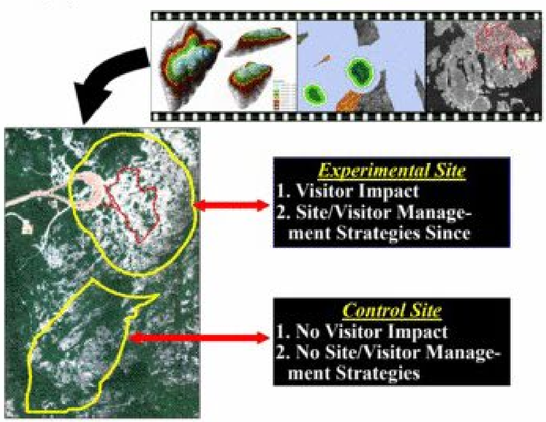
- Only mountain in Acadia National Park (ANP) with an automobile road.
- Approximately 75% of ANP visitors visit Cadillac Mountain (over 1.5 million/year).
- Extremely high visitor use in a small and sensitive area during summer.
- Slow recovery from damages caused by natural disturbance or recreational use.
- Both direct and in-direct management actions have been implemented since 2000.
- Ecological restoration project implemented in 2015.
- New vehicle reservation system implemented in 2021.



- Indirect management strategies (*red*) as signage which highlights the "Leave No Trace" principle
- Direct management strategies (*light blue*) as physical barriers (via woods/ropes)

Vegetation Cover Change Analysis

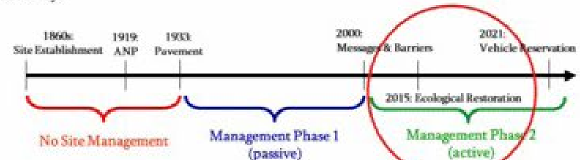
- Recreation ecology studies that have focused on vegetation change dynamics with recreational use over time have primarily concentrated on two major areas: (1) the amount of vegetation, with the impact parameter being vegetation cover, and (2) vegetation composition, with the impact parameter being species, species diversity, and frequency (Hammitt et al. 2015). Researchers have compared these measures at recreation sites (experimental) with similar measures at adjacent undisturbed sites (control) to better understand the vegetation change dynamics.



Study Objective

Direct/indirect management strategies (since 2000) Ecological Restoration Project (since 2015)

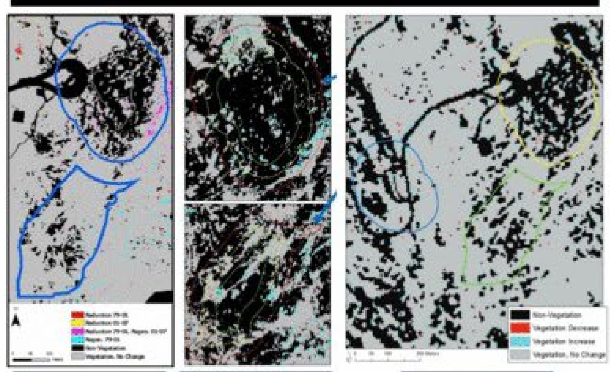
- A combination of site and visitor management strategies using physical barriers and low-impact educational messages were deployed strategically to address vegetation loss in 2000. More importantly, an ecological restoration project was newly implemented in 2015 to enhance vegetation recovery. Thus, our studies aimed to better understand vegetation change dynamics due to trampling in a fragile subalpine environment. Specific research objectives were to 1) detect direct vegetation changes resulting from visitor use by using a series of high spatial resolution remote sensing data and 2) verify the efficacy of the combined management strategies designed to reduce vegetation impact and enhance vegetation recovery.



Methodology

- **Data**: various high spatial resolution remote sensing data, including aerial photographs, NAIP, IKONOS, airborne, and Planet RapidEye (between 1979, 2001, and 2007, between 2001 and 2007, and between 2010 and 2018).
- **Vegetation cover change analysis**: Image differencing and vegetation index differencing based on the Normalized Difference Vegetation Index (NDVI) between the experimental site and the control site.
- **Image processing**: histogram matching, NDVI extraction, layer stack, and differencing & labeling (0: non-vegetation, 1: decrease, 2: increase, 3: vegetation, but no change).

Results & Discussions



Study 1: Between 1979, 2001, and 2007 | Study 2: Between 2001 and 2007 | Study 3: Between 2010 and 2018

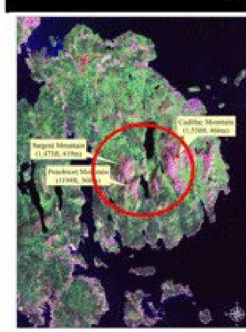
- **Results of Studies at Caillac Moutain Summits, Acadia National Park**

Spatial Scale (0-90m)		*Experimental Site (m^2)*			*Control Site (m^2)*		
		1979 - 2001	*2001 -2007*	*2010 - 2018*	*1979-2001*	*2001-2007*	*2010 - 2018*
Vegetation Decrease	**Study 1**	1,169	14		182	15	
	Study 2		23			180	
	Study 3			150			75
Vegetation Increase	**Study 1**	64	871		385	107	
	Study 2		1,668			791	
	Study 3			1,425			400

Study 1: Kim, M. K., & Daigle, J. J. (2011). Detecting vegetation cover change on the summit of Cadillac Mountain using multi-temporal remote sensing datasets: 1979, 2001, and 2007. *Environmental Monitoring and Assessment, 180*, 63-75.
Study 2: Kim, M. K., & Daigle, J. J. (2012). Monitoring of vegetation impact due to trampling on Cadillac Mountain summit using high spatial resolution remote sensing data sets. *Environmental management, 50*, 956-968.
Study 3: Kim, M. K., & Daigle, J. J. (2022). Long-term monitoring of vegetation cover changes by remote sensing, Cadillac Mountain summit, Acadia National Park. *Parks Stewardship Forum 38*:1.

- Before the combined management strategies (Study 1), the experimental site showed, unlike the control site, greater vegetation decrease than vegetation increase. However, the trend has changed since 2001 (both Studies 1 and 2), showing greater vegetation increase than vegetation decrease. Between 1979 and 2001, vegetation cover changes by natural variations at the control site showed greater vegetation increase and smaller vegetation decrease. In addition, between 2001 and 2007, the changes at the control site showed the same trend, greater increase, and smaller decrease. Between 2010 and 2018 (Study 3), both experimental and control sites showered greater vegetation increase than vegetation decrease. However, the amounts of both vegetation increase and decrease were higher in the experimental than in the control site.
- Given the low resilience characteristics of the subalpine environment at the summit, the trends observed (more vegetation increase and less vegetation decrease) suggest a desirable direction in terms of implementing management actions. However, continuous measurements of the vegetation condition over time will be required to assess the efficacy of the current management actions as well as to detect newly disturbed areas by visitor use and trampling. It is also expected that management recommendations could be developed for areas where the level of impact is high by measuring the recent vegetation cover changes at the summit. This information will be particularly beneficial to park/protected area managers for understanding the nature of visitor-induced impacts as well as prioritizing areas that need more intensive management.
- The vegetation cover change analyses based on remote sensing technology provide rapid and comprehensive assessments at Cadillac Mountain Summit. Due to a dense canopy cover and multiple vegetation layers, the value of remote sensing has not been well-recognized in the field of recreation ecology. However, the utility of remote sensing would be maximized in detecting vegetation cover changes, as the summit of Cadillac Mountain is an open landscape, having a mixture of sparse low-lying shrubs with bare rock dominant. Thus, this assessment method/approach could be effectively applied to other subalpine mountain summits with similar landscape conditions.

What's Next?



- **Save Our Summit (SOS) Project** with NPS, UMaine, UNLV, Navtive Plant Trust, Schoodic Institute:
  1) Ecological restoration
  2) Resource monitoring using further remote sensing data (between 2001 and 2021/2022), covering not only **Cadillac Mountain**, but also **Sargent and Penobscot Mountains**.
  3) ACAD Visitor Survey

Source: https://schoodicinstitute.org/how-to-save-a-summit/

Select Species of Concern, but an Overall Healthy Northeastern Forest after the 2023 Forest Health Monitoring Season

Jacob Vitale[1,2]; Alison Adams[1,2]; Soren Donisvitch[1,2]; Jerome Lee[2,3]; Benjamin Porter[1,2]; Elissa Schuett[1,2]; Matthias Sirch[1,2]; Nancy Voorhis[1,2]; Alexana Wolf[1,2]

[1]University of Vermont Rubenstein School of Environment and Natural Resources, [2]Forest Ecosystem Monitoring Cooperative (FEMC), [3] ECO Americorp Program - Vermont Department of Environmental Conservation

Through long-term forest health monitoring in seven (7) northeastern states, the Forest Health Monitoring (FHM) program has observed and analyzed relatively stable health conditions throughout the northeastern forest. However, due to specific damages and diseases, certain species should be continued to be closely monitored and managed, such as American beech and white ash.

Introduction

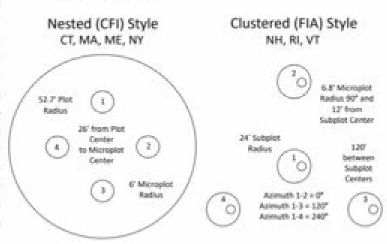
The FHM program of the FEMC has previously conducted long-term monitoring assessments of forest health throughout Vermont since 1990. As of 2023, the FEMC has established 194 total plots throughout Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (Fig. 4). These new sites were primarily co-located at established, long-term forest health monitoring plot locations through the Continuous Forestry Inventory (CFI) and the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) surveys, representing the major forest types and geographies on public lands.

During the 2023 field season, the FEMC FHM crews assessed seedling regeneration, sapling survivorship, and overstory health. Forest health metrics included tree heights, tree diameter at breast height (DBH), vigor, dieback, transparency, defoliation, and discoloration of the forest canopy. Lastly, crews documented special damages for each tree, along with invasive species presence and the degree of browse pressure observed within each plot.

Our primary analyses were focused on several different metrics: a temporal comparison of mean seedling density for each tree species (Fig. 2), comparing the FIA and the FEMC tree inventory of 2023 (Fig. 3), the average percent of vigor for each overstory tree species (Fig. 5), and the average dieback for each tree species, categorized by state (Fig. 6).

Figure 1. Our nested (CFI-style) (left) and clustered (FIA-style) (right) FHM plots are shown. Our FHM program adopted these to accommodate plot layouts from each state's historical FHM efforts. The nested plots contain an overstory plot (large circle) and four regeneration microplots (small circles at cardinal directions), while the clustered plots contain four subplots and four regeneration microplots, based upon the USFS FIA style plot network.

Plot Layout



Results

Starting with the forest floor, the FHM recorded relatively similar numbers of total seedlings of each species compared to previous years, particularly between the years 2022 and 2023 (Fig. 2). Large discrepancies between these years could be due to masting (e.g., red maple in 2023). Red maple was the most abundant seedling (35%), with balsam fir and sugar maple following after (15% and 14%, respectively). Continuing upward in the canopy, 1,094 total saplings were observed, with balsam fir and American beech representing the most abundant species.

Out of the 6,348 trees that we recorded (≥5 inch DBH), most species were similar in composition between the FHM and FIA programs except balsam fir, sugar maple, and American beech (Fig. 3). Vigor ratings for most tree species appear to be relatively similar in proportion, illustrating stable and healthy forests (Fig. 5). Lastly, dieback varied across the FHM region, with American beech and white ash having the largest averages and sweet birch having one of the lowest averages across states (Fig. 6).

Out of all diseases and damages recorded, beech bark disease was the most common (observed in 35% of plots with 74% of American beech showing symptoms), followed by emerald ash borer and hemlock wooly adelgid. Additionally, browse was most common in red maple (17.4 ft^2/acre) and sugar maple (17.2 ft^2/acre).

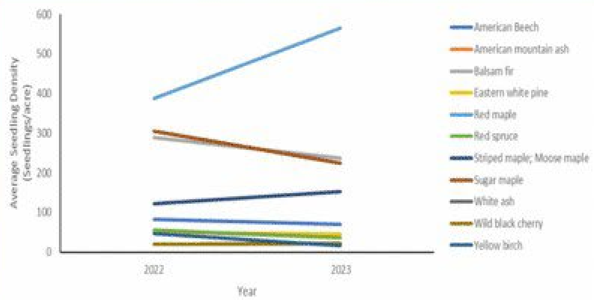


Figure 2. A temporal analysis of the mean seedling density (counts per acre) for each species between 2022 and 2023. Tree species with relatively high importance (abundance) values were included. Masting could also be the cause of large seedling discrepancies.

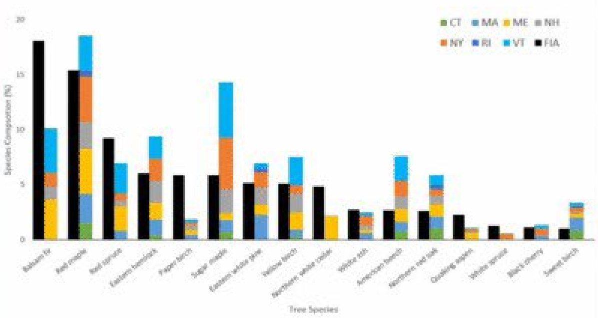


Figure 3. A comparative analysis between the FEMC FHM and the USFS FIA species compositions. Percent live species composition for CT, MA, ME, NH, NY, RI, and VT from both the FHM 2023 season and the FIA 2020 season were included (only trees with ≥5 inch DBH were included; USFS 2020).

FHM Program Plots in 2023

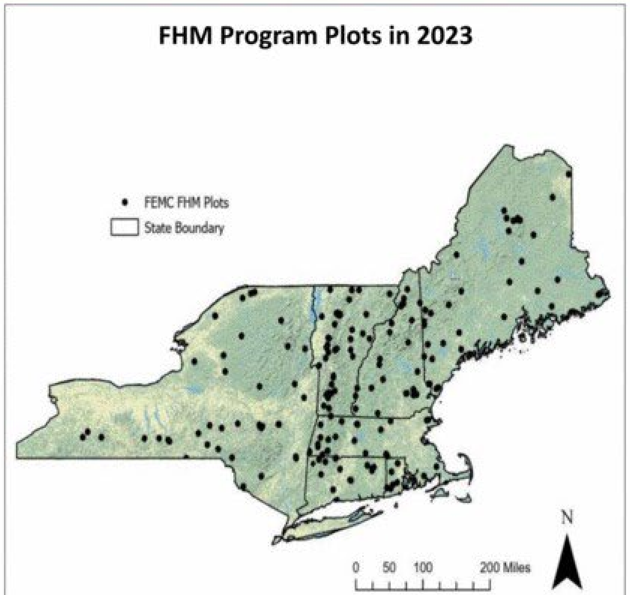


Figure 4. One hundred and ninety-four (194) plot locations were included in the total FHM analysis. As of 2022, our regional states include Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.

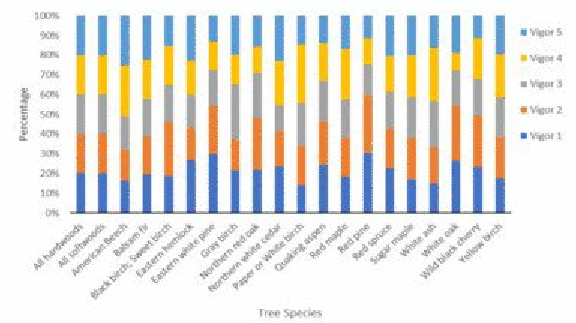


Figure 5. Average basal area per hectare (%) of each vigor (1 is healthiest, 2-4 is increasing decline, 5 is dead and standing) for each overstory tree species. Tree species with relatively high importance (abundance) values were included and only standing trees were included.

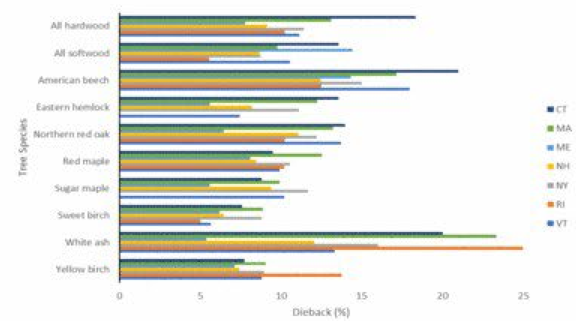


Figure 6. A comparison of average crown dieback (%) per species across seven (7) regional states. Crown dieback is identified as the percent of fine twig dieback and is rated from 0-100% (0% indicating no fine twig dieback, 100% indicating complete fine twig dieback). Tree species with relatively high importance (abundance) values were included.

Small Forest Owner’s Engagement with a Carbon Sequestration Effort in Northeastern United States

Frederick Pond, Vermont Forestland Owner

FEMC
2023 Annual Conference
Forests as Solutions to Climate Change, Biodiversity, and Well-being

Why I did it

- I wanted to go beyond the typical ways that are available to most of us to reduce our carbon emissions, e.g.
- I drive a hybrid gasoline vehicle, live in a super insulated home that is heated primarily by heat pumps, powered by solar; I choose lower carbon travel whenever possible.
- I realized my forestland could be an asset to address carbon warming.

Parcel

150 Acre Parcel
144.33 enrolled acres
Northwest Tunbridge

UVA MANAGEMENT PLAN SUMMARY FORM - 2020

Parcel ID: SPAN 657-207-10877
Town Located: Tunbridge
Plan Preparer: Redstart Forestry
Year of Entry: 1999
Year of last plan: 2020
Ortho Sheet #: Series 5000 148160; 2012
Total Forestry acres in parcel: 150

Std #	Acres	Age	Site	Type	MSD	TOT BA	AGS BA	Mgt	Date
1	99	1	1-2	11	10	82	49	13	2026
2	3	1	1-2	08	11	165	113	04	2023
3	35	2	1	06	12	83	59	7/8	2023

Mgmt Activities - other: Spot girdling in west central part of Stand 1. Treat invasive plants in stands 1 and 2. Timber types - other: Norway Spruce.

Reflections

- Will my forestland management plans be influenced by this contract?
- What if Vermont UVA requirements change, will there be conflict and compromise?
- Will this affect future land conservation interest or tree farm associations?
- How will future weather conditions affect carbon sequestration?

‘My forestland is the most powerful asset I have to make an impact on climate warming.’

Family Forest Carbon Program

- FFCP is a collaboration of The Nature Conservancy [TNC] and American Forest Foundation [AFF]; two conservation non-profits which operate the program through the Family Forest Impact Foundation, an affiliate of the AFF.
- FFCP enrollment allows me to improve my parcel through Vermont’s UVA Program, also known as ‘Current Use’; harvest firewood; and clean up after storms that pose a threat to safety and health.
- The *Enhance Your Woodland* practice offers payment of $200 per acre, spread over twenty years.
- Total paid 20 years/144.33 acres: $28,886.
- FFCP provides $2,400 for two forest management plans required for the UVA program.

Challenges

- No experience with TNC or AFF in this role, or any carbon sequestration organizations.
- Specific contract stipulations to follow.
- Twenty-year commitment.
- Limitations on land use, such as substantial harvest during contract period.

Advantages

✓ Recognizes Vermont Current Use Program goals.
✓ Firewood provision, storm clean up.
✓ Support for forest management plans for contract period.
✓ Contract termination provision.
✓ FFCP contract aligns with current & future management plans of forestland restoration and improvement.

fpond@uvm.edu or pondfc@yahoo.com

Resources

Family Forest Carbon Program
familyforestcarbon.org

Vermont Woodlands: What to consider when choosing a carbon program [Download Carbon FAQs document]
Vermontwoodlands.org

Northeast Forest Carbon Program [cooperative effort of Northeast region State Foresters]
www.northeastforestcarbon.org

UVM Extension: Forestry: Forest Carbon [2023]
https://www.uvm.edu/extension/forestry-forest-carbon

Northern Woodlands Forest Carbon Series [2023]
https://northernwoodlands.org/series/c/forest-carbon

Forest Carbon An essential natural solution for climate change [current as of 2019]
https://necasc.umass.edu/biblio/forest-carbon-essential-natural-solution-climate-change

How Can Family Forests Help Mitigate Climate Change? [current as of 2022]
https://www.sustainablewoodstock.org/forest-carbon-management/

Summit-to-Shore Snow Observatory Network in Vermont

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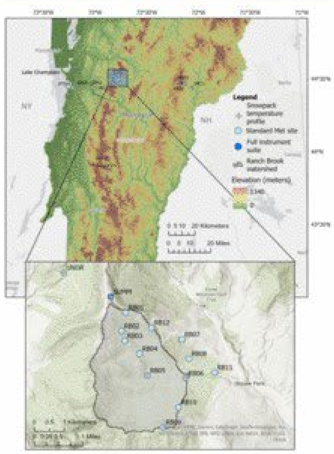
INTRODUCTION

This Summit-to-Shore (S2S) observatory network aims to monitor snowpack characteristics and meteorological variables at a high spatial and temporal resolution across an elevational transect in the Vermont. Traditional meteorological measurements combined with detailed snowpack measurements will provide high resolution observational data as forcings and validation for computational snowpack models. In addition to these data, remotely sensed snow depth collected via UAV and LiDAR will provide further insight to characterize snowpack evolution in response to varying forest cover, topography, and meteorologic drivers. This will help augment research in a low-elevation montane environment that is understudied with respect to snowpack dynamics.

STUDY AREA



PTSH	Potash Brook (45m)
SPER	Spear St (87m)
JRCL	Jericho Clearing (199m)
JRFO	Jer. Forested (196m)
SUMM	Mansfield Summit (1169m)
UNDR	Underhill (698m)

RB##	Ranch Brook (390m-1170m)
SR01	Sleepers River (552m)
SR25	Sleepers River (356m)
SR11	Sleepers River (225m)
PROC	Proctor Maple (418m)

PRELIMINARY RESULTS

Seasonal snow depth measurements were captured across an elevational gradient. These snow depths are stratified elevationally for the most part, depicting elevation as a major contributing variable to snowpack depth.

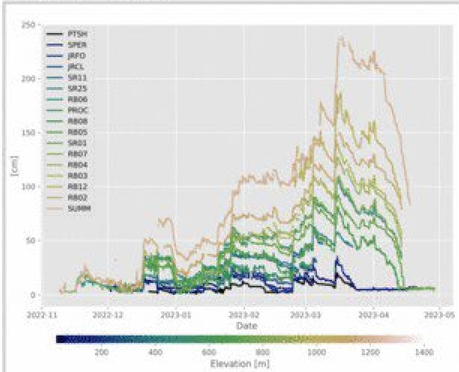


Figure 1: Seasonal snow depth evolution

Snowpack accumulation and ablation as a function of elevation is shown below. Accumulation is largely elevation dependent, but this relationship is variable across different events.

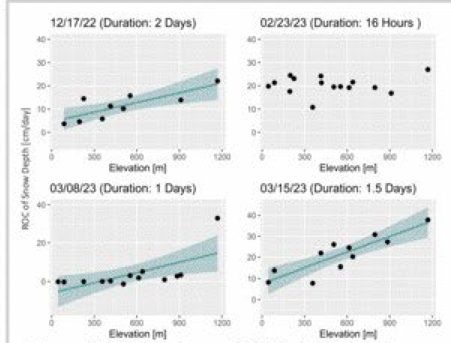


Figure 2: Rate of change (ROC) of snowpack accumulation across an elevational gradient

Ablation events are highly event-specific and are dependent on factors other than just elevation.

Met Station at Site RB12

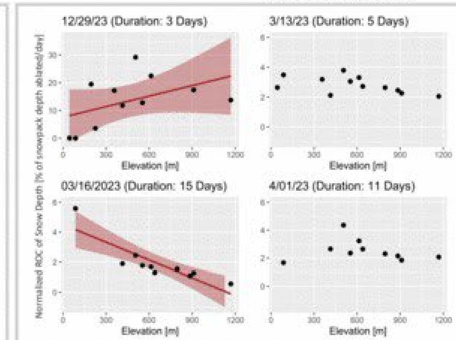


Figure 3: Normalized ROC of snowpack ablation across an elevational gradient

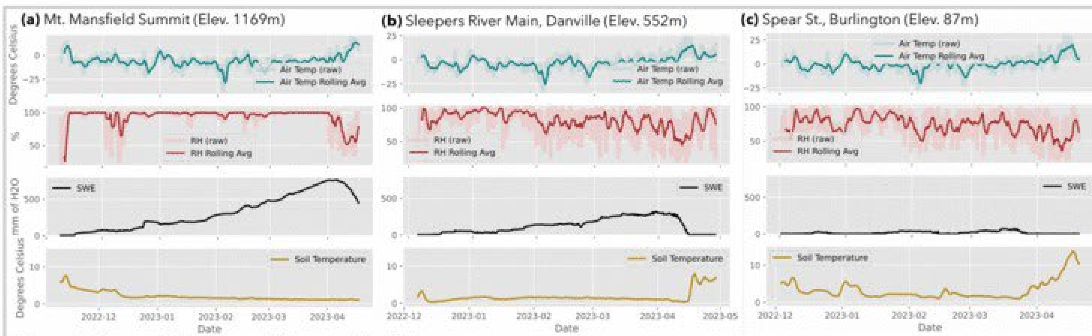
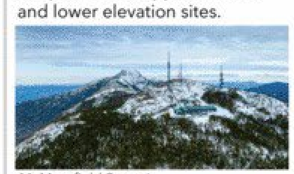


Figure 4: Seasonal Evolution of Measured Variables

In addition to snowpack depth, other meteorological and hydrological were documented across each site. Figure 4 shows the seasonal evolution of temperature, relative humidity, SWE, and soil temperature at upper, middle, and lower elevation sites.



Mt Mansfield Summit

FUTURE WORK

Future work will involve the leveraging of these high-resolution data to drive and validate a distributed snowpack model, which will be used to address the following research questions:

- What are the major landscape determinants of snowpack distribution in Vermont?
- How is snowpack ablation occurring across an elevational gradient, and what are the meteorological and climatological drivers?
- How well does a model represent anomalous mid-winter warming events and their effects on snowpack ablation? How can we characterize these events and their impact on SWE?

The Ecological Scorecard Project: Monitoring in the Adirondack Park, NY

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Introduction

In recent years, human recreation on many public lands has increased, including in the Adirondack Park. To assess how the park's natural and recreation resources are responding to visitor use, we partnered with the New York State Department of Environmental Conservation in 2019 to implement the Ecological Scorecard project.

This long-term monitoring project assesses how selected areas may be changing over time due to recreation. Identifying trends in such areas alongside visitor use allows for evidence-based management, and continued monitoring of how such management action may help to improve ecological outcomes. This process enables a feedback loop of adaptive management.

Sampling sites

Since 2020, we have sampled up to 16 points of interest (POIs) used for recreation (e.g., campsites, lean-tos, and trails), a trail not yet open to the public, and two non-recreational control sites in ESF's Huntington Wildlife Forest, Newcomb, NY. Recreation sites are on DEC lands designated as Wilderness, Wild Forest, or Primitive Area (Fig. 1).

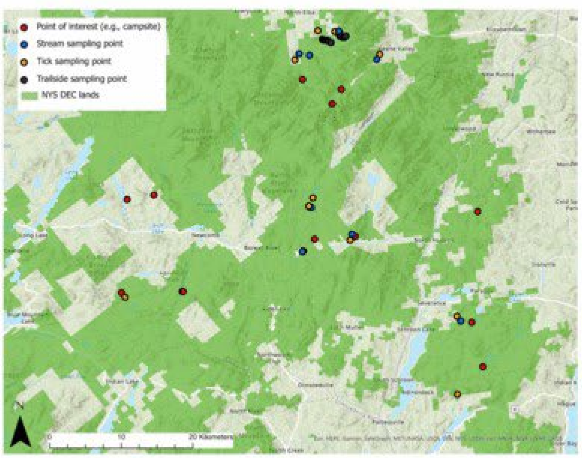

Fig. 1: Locations sampled in 2022 as part of the Ecological Scorecard monitoring project in Adirondack Park, NY.

Methods

At each point of interest, we sample a suite of ecological indicators from which inferences on recreation can be made. Monitoring is carried out in several settings: randomly oriented transects, 1m² quadrats, standardized photo-points (Fig. 3, 4), and point surveys of indicators.

Red indicators show potential problems; blue indicators show limited recreation impact:

- Ticks at trailheads and edges of parking areas.
- Salamanders.
- Invasive earthworms.
- Percent coverage of different ground cover types (e.g., bare soil, rock, moss, and woody vegetation).
- Percent vertical structural complexity (VSC) measured 0–0.5m and 0.5–1m above ground (Fig. 2).
- Audio data of human sounds and vocalizations of wildlife.
- Invasive plants, forest pests and diseases.
- Loons at sites with adjacent lentic waters.
- Macroinvertebrate communities at sites with adjacent lotic waters:
  - Pollution-sensitive taxa and pollutant-tolerant taxa.

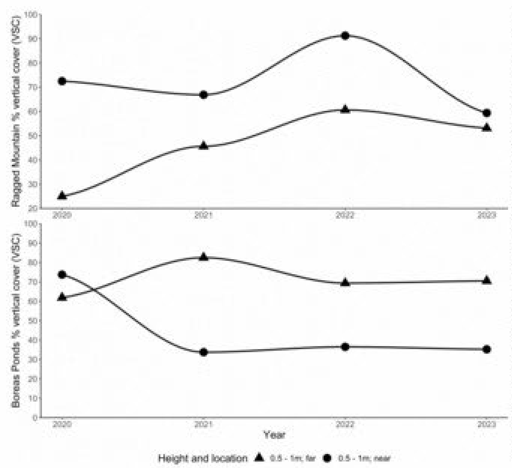

Fig. 2: % VSC near and far from two different POIs sampled 2020-2023. Top: VSC near and far from the POI remain stable, suggesting limited recreation impact. Lower: Decreasing VSC near the POI suggests impact.

Analysis and scoring

Trend analyses to monitor change in indicators through time are ongoing. Our monitoring methods include comparing recreational sites with control sites and comparing cover/structure sampled adjacent to points of interest (near plots) with cover/structure sampled 100m from the point of interest (far plots), where recreational use is less likely (Fig. 2).

We assign each site a score based on a semiquantitative index to summarize its current condition and changes in its condition across time. The index weighs quantitative ecological indicator data and qualitative information, such as visually apparent change in erosion (Fig. 4) and presence of trash.

Fig. 3: Photographs of a site used for rock climbing. Erosion and hindered vegetation growth is visible in the left photograph, whereas an unused section at the base of a rock wall supports vegetative growth on the right.

Fig. 4: In the left photograph, a frequently used trail (Cascade Mountain), exhibits exposed rocks, soil erosion, and compaction from high visitor use. The photograph on the right shows a new trail constructed with a moderate grade that aims to minimize erosion once open for recreation.

Acknowledgements: We thank the stalwart field technicians and the New York State Department of Environmental Conservation's Division of Lands and Forests for funding and guidance. Questions to the agency regarding the project may be guided to Sara Hart at sara.hart@dec.ny.gov.

Thermal Calendars to Inform Management in a Changing Climate

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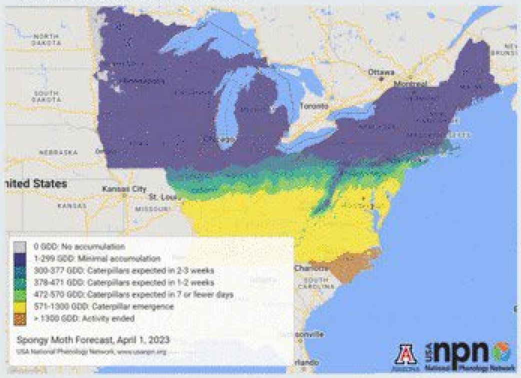
What are Thermal Calendars?

- Climate change is shifting the seasons: events like flowering don't necessarily occur at the same time now as they have in the past.
- In the Northeast, climatic variations can shift phenophases across locations by several weeks
- Old survey guides based on the calendar like *"scout for spongy moth in late May"* may no longer hold.
- Timing seasonal activities such as scouting for spongy moth can be improved using phenology based methods and tools, where local conditions (primarily temperature) are integrated to estimate and forecast life history stages for key forest species.
- **Thermal Calendars** are dynamic maps that can describe when and where species are meeting key developmental thresholds.



Example Thermal Calendar map indicating the date that Spongy Moth caterpillars emerged across states in the northeastern U.S. in 2023.

Successful management of invasive species requires monitoring/control actions to coincide with life stages when the target species are most vulnerable to treatments. Land managers have requested location-specific action treatment dates from USA-NPN. Thermal Calendars are a tool to support them.

How might this help me?

High quality data and tools are critical to land management, but their utility is limited if they are not delivered and communicated in ways that make them readily available to a wider audience of practitioners. By understanding and integrating the social and cultural values that managers, agencies and organizations bring to management, tools may be more effectively delivered and applied.

We will engage decision makers, Tribal representatives, and natural resource managers in an effort to better understand what shapes their decisions and in co-producing data products to support on-the-ground management.

Example events indicated by Thermal Calendars

Management of Insect Pests:
Best timing for biocontrol agents, monitoring life stages for targeted survey and management activities:

- Emerald Ash Borer
- Hemlock Woolly Adelgid
- Spongy Moth

Emerging Pests/Pathogens:
Optimal timing for surveillance of other pests and pathogens of interest:

- Elm zigzag sawfly
- Spotted lanternfly
- Oak wilt

Native Plants of Interest:

- Seed ripening/optimal time to harvest seeds in native plants such as ash, beech, oak
- Bloom time for key nectar plants such as serviceberry, milkweed, red maple
- Sap flow in sugar maples

Next steps

Winter-spring 2024
Interviews, surveys and stakeholder workshops to solicit input and to learn about the values shaping management decisions - we need land manager input from all sectors!

Spring-summer 2024
Draft maps available for feedback

Fall 2024-winter 2025
Final maps live through USA-NPN website, visualization tool, data download

- Day of year GDD thresholds met each year, 1990-2023
- Average day of year thresholds met (1990-2020)
- Day of year GDD thresholds met in current year - maps updated nightly

Spring 2025
Trends in timing of thresholds mapped across study region

How can I help?

If you would like to be a part of the co-production of knowledge for this project and the eventual products, please add your email and phone number to the google form connected to the QR code and indicate what level of engagement you are interested in!

QR code to Google Form

Or sign up for USA-NPN newsletters to keep up!

This work is supported by the U.S. Geological Survey Northeast Climate Adaptation Science Center.

Using Point Counts to Study How Forestry Management Affects Avian Communities

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Introduction

- Climate change is having negative effects on habitats & species in the northeast[1,2]
- Adaptive silviculture for climate change (ASCC) practices consider climate change as part of habitat management strategies[3]
- ASCC is a national collaborative effort between mangers and scientist that establish experimental trials in different types of forest habitats
- This research sought to answer the following:
  - How do adaptive management practices affect northeastern avian communities?
  - How will passive acoustic recorders estimate songbird occupancy in forested habitats (future)?

Methods

- Focus on breeding birds in VT and NH
- Acoustic recorders were paired with camera traps as part of the New England ASCC network
- Study areas were the Nulhegan Basin, Silvio O. Conte Refuge (VT) and Mount Jefferson (NH)
- Avian point counts were conducted for 42 points from May-July beginning at sunrise for about 5 hours

Fig 1: Recording Points on Mt. Jefferson

Oh! Look a camera!

Results

Table 1: Top 5 Most Detected Species

Species	Nulhegan	Mt. Jefferson
WTSP	83	2
SWTH	37	16
OVEN	68	10
YBFL	42	18
WIWR	39	24

Table 2: Alpha Diversity

Site	α Diversity
Nulhegan	74
Mt. Jefferson	32

β=77

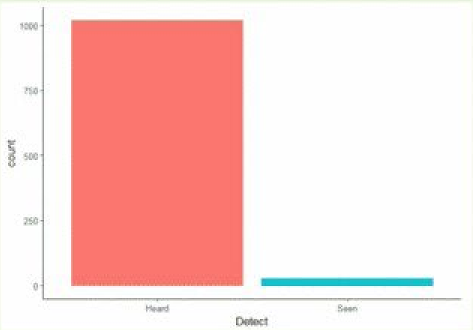

Fig.2
How were the birds detected?

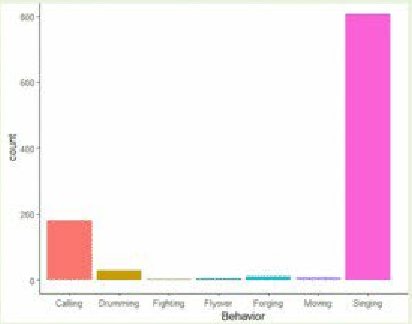

Fig.3
Observed Behaviors

Future Directions

- Expand passive acoustic analysis to get a more complete picture of the avian community
- Analyze the impacts of different management practices on avian communities
- Addition of sites that use fire management in the Northeast

Acknowledgements

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Work Cited

1. Rodenhouse et al. 2008. Potential effects of climate change on birds of the Northeast. Mitig. Adapt. Strat. Glob. Change 13:517-540.

2. Jay et al. 2023. Ch1. Overview: Understanding risks, impacts, and responses. Fifth National Climate Assessment.

3. Nagel et al. 2017. Adaptive Silviculture for Climate Change: A National Experiment in Manager-Scientist Partnerships. Joun. of Forestry 3: 167-178.

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